Implications for the future of fisheries as extractive industries in the creation of sustainable places.

A case-study of the Sustainable Supply Chain Management of the Lipsi coastal Small-Scale Capture Fishery supply chain, Greece.

by

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A thesis submitted in fulfilment of the requirements for the Degree of
Doctor of Philosophy

Sustainable Places Research Institute
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To my parents

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ABSTRACT

"A supply chain encompasses all activities associated with the flow and transformation of goods from the raw materials stage (extraction), through to the end user"

Handsfield and Nichols, 1998

There exists a lack of information about many of the social, economic and ecological links within coastal Small-Scale Capture Fisheries; such knowledge is pertinent to the future sustainable exploitation and management of marine ecosystems by coastal communities. To conserve natural resources for future generations, sustainable management of natural resources is necessary. Sustainable resource management can help ensure that the use of resources does not cause an imbalance in the environment, and increasingly, sustainable management practices are being encouraged to preserve both animal and plant life for the benefit of future generations.

Supply Chain Management is the active management of supply chain activities. It represents a conscious effort by supply chain managers to develop and run supply chains in the most effective way to meet Consumer demand. However, the vast majority of research and practice regarding sustainable supply chains has followed an instrumental logic, which has led firms and supply chain managers to place economic interests ahead of environmental and social interests.

Ecologically Dominant Sustainable Supply Chain Management is a planning and decision-making process that seeks to coordinate and balance the social, economic and environmental demands of resource use to achieve long term sustainability. In this thesis, the Sustainable Supply Chain Management of the Lipsi Small-Scale Capture Fishery has been approached from a Sustainable Supply Chain Management perspective. The thesis interrogates the seafood supply chain of 'place' (The Municipality of Lipsi) by taking into consideration each 'stage' of the seafood supply chain; expressed here as Habitat, Assemblage, Fishery, Market and Consumer.

In adopting q novel Conceptual Framework this thesis provides a platform for Small-Scale Capture Fishery research to move beyond 'Catch to Market' thinking (that treat's the ocean as a 'black box' or homogenous entity) and helps to articulate the heterogeneous roles that coastal habitats play in provisioning Small-Scale Capture Fishery seafood supply chains. Furthermore, it aims to provide an intuitive and accessible platform for inter-disciplinary discussion, be that between business managers, ecologists, socio-ecological researchers, fisheries managers or local stakeholders

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LIST OF ACRONYMS

3BL – Triple Bottom Line

ABT – Apnea Belt Transect

ACFR – Advisory Council on Fisheries Research

ANOSIM – Analysis of similarity

ANOVA – Analysis of variance

APC – Apnea Point Count

ARS – Aerial Remote Sensing

ASC – Aquaculture Stewardship Council

ASG – Agricultural Statistic of Greece

BOFFFF – Big Old Fat Fecund Female Fish

BRUV – Baited Remote Underwater Video

CEc – Capital stock of the Economy

CEn – Capital stock of the Environment

CESR – Corporate Ecosystem Services Review

CF – Conceptual Framework

CFP – Common Fisheries Policy

CLUSTER – Cluster analysis

CPUE – Catch Per Unit Effort

CR – Critically Endangered

CRN – Catch and Release Nets

CS – Capital stock of the Society

CSD – Capital stock of Sustainable Development

DCM – Demand Chain Management

DFID – Department for International Development

DJI – Dà-Jiāng Innovations Science and Technology Co., Ltd

EBFM – Ecosystem Based Fisheries Management

EC – European Commission

ED – Ecologically Dominant

ELSTAT – The Hellenic Statistical Authority

EMA – Environmental Management Accounting

EN – Endangered

ESP – Ecosystem Service Providers

EU – European Union

EUROPA – The official EU website that provides access to information published by all EU institutions, agencies and bodies.

EUROSTAT – The Eurostat Dissemination Database provides official statistics on the European Union, EU member states and sub-state regions

FAO – The Food and Agriculture Organization of the United Nations

FCA – Full Cost Accounting

FEK – Fishers Ecological Knowledge

FLD – Fisheries Landings Data

FOV – Field of View

GDP – Gross Domestic Product

GIS – Geographic Information System

GPS – Global Positioning System

GSCM – Green Supply Chain Management

GSD – Ground Sampling Distance

IMF – The International Monetary Fund

IPBES – The Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services

IPCC – The Intergovernmental Panel on Climate Change

ISO – In-Situ Observations

ISO – International Organisation for Standardisation

ITQs – Individual Transferable Quotas

IUCN – The International Union for Conservation of Nature

LC – Least Concern

LCA – Life Cycle Assessment

Lm – Length at Maturity

LSCF – Large-Scale Capture Fisheries

MaxN – Sample maximum

MCSUK – Marine Conservation Society United Kingdom

MDGs – Millennium Development Goals

MDS – Multidimensional scaling

MEA – Millennium Ecosystem Assessment

GOC – Global Ocean Commission

MEZ – Marine Exclusion Zone

MLS – Minimum Landing Size

MPA – Marine Protected Area

MSC – Marine Stewardship Council

MSY – Maximum Sustainable Yield

MTI – Marine Trophic Index

NCP – Natural Capital Project

NMDS – Non-metric Multidimensional scaling

NOAA - The National Oceanic and Atmospheric Administration

NRBV – Natural Resource Based View

NVI – Natural Value Initiative

OECD – Organisation for Economic Co-operation and Development

PRIMER – Plymouth Routines In Multivariate Ecological Research

PVA – Population Viability Analysis

RAM – Random-access memory

RFD – Reported Fisheries Data

RHS – Resident Household Survey

SCM – Supply Chain Management

SDG – Sustainable Development Goals

SE – Standard Error

SEK – Scientific Ecological Knowledge

SES – Socio-Ecological Systems

SIDS – Small Island Developing States

SIMPER – Similarity Percentages

SSCF – Small-Scale Capture Fisheries

SSCM – Sustainable Supply Chain Management

SSF – Small-Scale Fisheries

STECF - Scientific, Technical and Economic Committee for Fisheries

TAC – Total Allowable Catch

TBTI – Too Big To Ignore

TED – Turtle Excluder Device

TL – Total Length

TLEK – Traditional and Local Ecological Knowledge

TURFs – Territorial User Rights

UAV – Unmanned Aerial Vehicle

UN – United Nations

USD – United States Dollar

UVC – Underwater Visual Census

VES – Visitor Exit Survey

VTS – Vessel Tracking Systems

VU – Vulnerable

WCED - World Commission on Environment and Development

WSFC – World Small-Scale Fisheries Congress

WWF – World Wildlife Fund

CHAPTER 1 – Introduction

1.1 Sustainability science

Etymologically, the word sustainability is derived from the Latin (sustinere) and can mean “maintain”, “support” or “endure” (Dictionary.com). However, within sustainability science, the word is now often seen through the lens of sustainable development, defined in 1987 by the Brundtland Commission as:

“… development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

World Commission on Environment and Development (1987, p.43)

This definition implicitly recognises the necessity for resource consumption [development] occurring at a rate which can be sustained perpetually [future generations]. Since the Brundtland Commission report, there have been numerous definitions of sustainability, but most refer to the viability of natural resources and ecosystems over time, to the maintenance of human living standards, and to the desire for economic growth.

Sustainability science has emerged in the 21st century as a new academic discipline (Kates et al., 2001). Sustainability science is difficult to conceptualise, plan and conduct, given the broad range of epistemological commitments, methodological practices, and approaches to problem-framing taken by its constituent disciplines (MacGillivray and Franklin, 2015). Sustainability is often considered as the capacity of a given process to endure indefinitely, and within the biological sciences’ literature, is often characterised by systems that remain productive in perpetuity. Forests, meadows, reefs and mangroves are all examples of ‘[eco]systems’ that have maintained their productivity over extended timescales.

However, a caveat to this definition is that ecosystems are inherently dynamic. Even in a stable state a system’s productivity will vary. It is therefore the ‘resilience’ of ecosystems that has become the focus of much current research. Resilience is the capacity of a social-ecological system to absorb or withstand perturbations and other stressors whilst maintaining its structure and functions (Walker et al., 2004). Here the focus is on understanding how ecosystems can undergo 'regime shifts' from one (usually productive) stable ecosystem into a radically different (usually less productive), yet stable state.

The organising principle for sustainability science is sustainable development, which includes the three interconnected systems of ecology, economics and society (ecological, economic and social systems). The journal 'Sustainability Science' (ISSN: 1862-4065 [Print] 1862-4057 [Online]) describes itself as exploring;

"the complex mechanisms that lead to degradation of these systems, and concomitant risks to human well-being"

Springer.com, 2016.

with the aim to create a;

"*transdisciplinary academic structure and discovery processes that fuses the natural sciences, social science and humanities*"

Springer.com, 2016.

Indeed, Sustainability Science has defined itself by the problems it addresses rather than by the disciplines it employs (Clark, 2007). This position provides a platform for building sustainability science as a new discipline that can promote a sustainable global society by facing challenges that existing disciplines have struggled to address. These include efforts to;

"*simultaneously understand phenomena and solve problems, uncertainty and application of the precautionary principle, the co-evolution of knowledge and recognition of problems, and trade-offs between global and local problem solving"*

Springer.com, 2016.

A primary hurdle in conducting a systematic literature review of "sustainability" stems from the breadth and contestation of the term across the disciplines. Sustainability relates to various parallel terms within the business management literature, including 'corporate and social responsibility' and 'ethics', and to many subsidiary terms relating to elements of sustainability (Network for Business Sustainability, 2011). For a transdisciplinary thesis such as this, a deliberately broad approach has been adopted, one which follows Carter and Rogers (2008) concept of sustainability:

"three components: the natural environment, society, and economic performance [which] corresponds to the idea of the triple bottom line, a concept which simultaneously considers and balances economic, environmental and social goals from a microeconomic standpoint"

(Carter and Rogers, 2008: p.364)

The popularity of this conceptualisation of sustainability also stems from a simple model to facilitate comprehension of the term; represented by Dreo (2006) in a Venn diagram (Figure 1), where sustainable development is at the confluence of three constituent systems. This model has proved a popular and palatable way of relating the conceptual complexity of sustainability to a wide audience (Moir and Carter, 2012) and similar representations have been adapted for specific contexts and interests, e.g. industry recasting the dimensions as people, planet and profit (Elkington 1998).

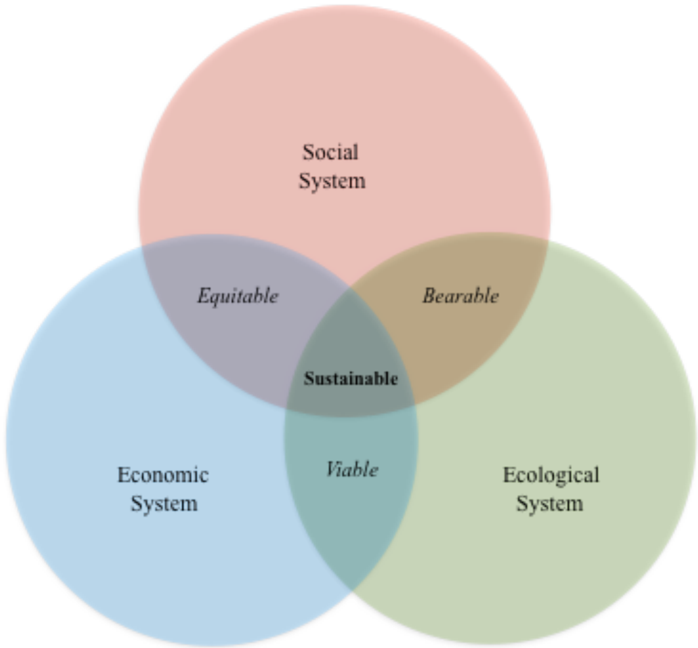


Figure 1. Venn diagram of sustainable development. Sustainability is achieved at the confluence of the social, economic and ecological systems. Adapted from Dreo (2006)

However, this model doesn't present a 'baseline' or scale at which sustainability is achievable. For example, when working with faunal (animal) populations they work on thresholds in terms of population viability. Population Viability Analysis (PVA) is widely applied in conservation biology to predict extinction risks for threatened species and to compare alternative options for management (Brook et al., 2000). For a given species, the viability threshold may be in the thousands of individuals, yet once the Population Viability threshold is breached, the loss of one individual tips the population into unsustainability and eventual collapse. A nuance to this model is also that of population 'concentration', one hundred Mediterranean monk seals in Greek waters is an entirely different proposition to the same number split between Morocco and Greece, with no chance of the two populations meeting to produce offspring.

Whilst the Dreo approach is inherently oversimplified (Giddings et al., 2002; Moir and Carter 2012) it has been useful for informing research and discussion and for informing future management decisions. However, perhaps the sharpest criticism of this model is that it inadequately considers scale and the dynamic processes of change over time (Lozano, 2006)

Critical to informed sustainability thinking is the understanding of historical productivity and ecological baselines. This originates in the ‘capital stock model’ of sustainable development and helps to contextualise what we are trying to sustain i.e. the enormous ‘Grand Banks’ of North Atlantic Cod, or the transient dynamics of an altered ecosystem (Myers et al., 1997; Frank et al., 2011).

In 1994, The World Bank promoted the following capital stock model:

Capital stock of Sustainable Development (CSD)

=

∑ ***Capital stock of the Environment (CEn)***

+ ***Capital stock of the Economy (CEc)***

+ ***Capital stock of the Society (CS)***

This articulates that if society lives off only the interest, and not the capital, the basis of prosperity is maintained. However, if society consumes the available capital, our continued existence is endangered because the interest erodes over time. The definition of *Ecological Capital* here relates to natural resources provided by ecosystems and biodiversity. *Social Capital* and *Economic Capital* equates to human health, education, social security and cohesion, freedom, justice, equality of opportunity and peace (Daly and Silver, 2008, Costanza et al., 2014). The challenge for the Capital Stock Model is how far different capitals can be interchanged (e.g. ‘Environmental Capital’ turned into ‘Economic Capital’, or ‘Economic Capital’ turned into ‘Social Capital’).

The degree to which different capitals can be interchanged is articulated by the concepts of ‘strong’ (or ‘hard’) sustainability and ‘weak’ (or ‘soft’) sustainability. Strong sustainability requires that none of the three individual types of capital should be eroded; whilst weak (or ‘soft’) sustainability only requires this for the aggregate capital stock. Weak sustainability allows reductions in environmental or ‘Natural Capital’ if it is compensated for by increasing Economic or Social Capital. Some commentators advocate an intermediate position between strong and weak sustainability as long as ‘threshold values’ e.g. excessive Natural Capital erosion (overexploitation) are not reached.

Critically, under the capital stock model, “Natural Capital” forms the platform upon which “Social” and “Economic Capital” is created. This hierarchical approach forms the basis of much of today’s coupled systems’ thinking, where the Socio-Economic Systems / Social and Economic Capital are wholly dependent on the Ecological System / Natural Capital. The hierarchal nature of this thinking has been represented by Cato (2009) using three overlapping ellipses demonstrating that the ecological system will constrain both the social and economic systems (Figure 2)

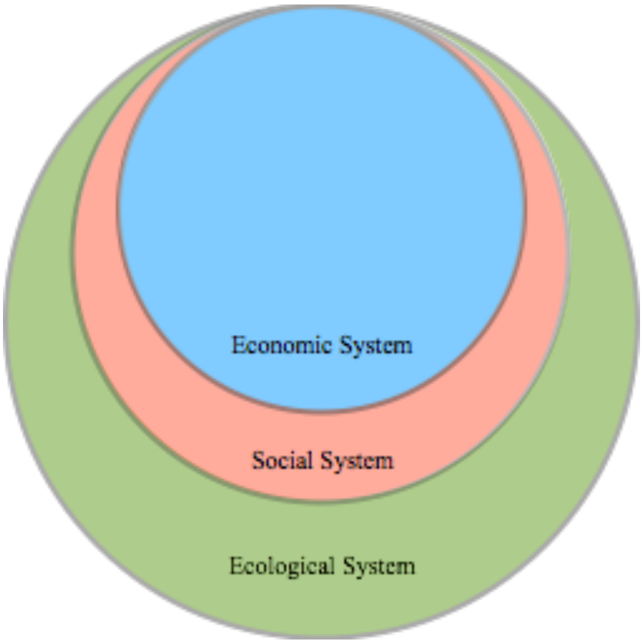


Figure 2. An illustration of overlapping ellipses indicating the ‘three pillars of sustainability’ Here both the economic system and social system are constrained by ecological system. Adapted from Cato (2009)

Giddings et al. (2002) argue that almost all human activities are dependent on (and impact on) the natural environment, and that furthermore the economy represents a subset of society. Therefore, in contrast to the Venn model with its suggestion of equivalency between the dimensions, a hierarchical model with nested circles is a more appropriate depiction of sustainability. Note that the environment can still exist if society is no longer present (Lovelock 1988) and, at least in some locations and on some scales, society can persist without an extant economy (Moir and Carter, 2012).

1.2 Place-based research into Socio-Ecological Systems

Within the last decade, significant progress has been made in interdisciplinary investigation and modeling of these hierarchical coupled social-ecological systems (socio-economic systems and ecological systems). Various approaches have been developed in which the interaction between the social and economic system (hereafter socio-economic) and the ecological system are explicitly considered (Young et al. 2006; Folke 2006; Liu et al. 2007; Östrom 2007; Binder 2013). Concomitantly, frameworks have been developed to structure research into socio-ecological systems, and to provide guidance toward a more sustainable development of socio-ecological system research (Allen and Holling, 2002; Östrom, 2009, Pahl-Wostl 2009, Scholz 2011). However, these frameworks differ notably in their goals, their applicability, their temporal and spatial scales, and in some cases their conceptualisation of what socio-ecological systems entail (Binder et al. 2013).

Within linked socio-ecological systems the properties of each social system are influenced by the properties of the natural system on which they depend (Kates et al, 2001; Adger et al, 2005a, 2005b; Wu, 2006; Ash et al, 2010). The dynamics of these linked systems are often determined by feedback loops operating between them (e.g. Folke et al, 2010; Valdés- Pizzini et al, 2012). There is a growing body of research exploring the issues facing societies dependent upon natural resource extraction, most notably the links between resource depletion and socio-economic decline, often due to unsustainable natural resource management approaches (Adger et al, 2005b; Liu et al 2007; Valdés-Pizzini et al, 2012). Communities have long experienced resource booms and busts, as each society's continued existence is determined against various criteria of environmental sustainability (Pilgrim et al. 2007).

Place-based research begins by defining the 'place' under consideration, which relates to scale and the unit of analysis, both with regards to the socio-economic, and the ecological system. Regarding socio-economic systems, much of the literature seeking the links between social and economic performance of 'places' has drawn on the concept of Putnam's (1993) 'social capital' (e.g. Schneider et al., 2000; Beugelsdijk and Van Schaik, 2005), with research suggesting that variations in the social system will have a causal effect in the development of the economic system and vice versa (Tabellini, 2010). This has led to calls for further analysis of regional and local culture, identity and mentality that capture the '*regional* [place-based] *self'* (Syssner, 2009). This field of research explores 'transitions of place' caused by negative socio-ecological feedbacks that arise, for example, from a depletion of key resources or from socio-economic change. These feedbacks have become the focus for several studies (Berkes, 2002; Ostrom et al., 2007; Adger et al., 2009; Lambin and Meyfroidt, 2010). There is a bifurcation in the research literature when it comes to scale of place, with the global change domain analysis considering the large-scale global processes such as climate change and biodiversity loss, with discussion as to what these changes mean to humans and to the environment that sustains us (Cutter et al, 2008).

However, whilst the scale of processes such as overfishing is global (Jackson et al, 2001; Pauly et al, 2002; Pauly et al; 2005) the unit of analysis varies from the local to the regional (Atta-Mills et al, 2004; Cinner et al, 2006; Reis-Filho et al, 2016), with each scale and unit of analysis requiring a unique vocabulary and nomenclature. For example, at the household level, (a favoured unit of analysis, within for example, the UKs Department for International Development (DFID) Sustainable Livelihoods Framework (see Scoones 1998, Carney 1998)) issues of entitlement and livelihood come into play, yet at the regional and global scale, Gross Domestic Product (GDP) is often used as an indicator of community resilience (Pelling, 2003; Cutter et al, 2008).

Despite recent advances in our understanding of socio-ecological processes, 'place-based' research continues to be required to contextualize social, economic and ecological processes at any given place and time. Place-based research has been described as research focusing on the *"interactions between nature and society"* (Kates et al, 2001), investigating *"the connection between environmental issues and people"* (Ash et al, 2010) and involving the understanding of *"ecological and social characteristics of particular places and sectors"* (Potschin and Haines-Young, 2012). Social-ecological systems consist of bio-geo-physical units (nature) with the associated actors and institutions (society). Understanding these systems is the core focus for sustainability science seeking to understand the character of interactions between nature and society and '*to encourage those interactions along more sustainable trajectories"* (Kates et al, 2001). Through integrated (social, economic, ecological) place-based research management, measures can be identified to meet these goals.

Key to the successful application of a research framework is the explicit recognition of temporal and spatial scale, or what constitutes the 'place' under consideration. Place is a useful 'boundary device' for sustainability science, providing a platform for integrative work, guiding theoretical reflection, encouraging methodological innovation, and informing empirical research (MacGillivray and Franklin, 2015). Figure 3 represents a conceptualisation of the coupled-socio ecological system surrounding the Lipsi fishery to be explored within this thesis. Under this place-based conceptualisation the fishery spans both the ecological and socio-economic systems, and where drivers of socio-economic change (e.g. more efficient fishing equipment) will drive change in the ecological system (a decrease in the number of fish).

Through localised study of the complex and dynamic interrelations between ecology, society and economy it is possible to pursue the creation and continued longevity of 'sustainable places'. The importance of 'place' is in providing a geographic, social and economic context in which problems can be recognised, values articulated, and appropriate management measures proposed. For the effective implementation of strategies working towards sustainability to be effective, solutions need to be relevant at scales relevant to the specific places. For example, management solutions for coastal management in the Wakatobi National Marine Park, Indonesia will inevitably differ in some respects from solutions aimed at protecting the Coral Triangle more generally, since the Coral Triangle region is much larger and includes six countries each with their own socio-economic systems.

For most people, the sustainability of their own community matters more to them than sustainability in distant communities, and yet sustainability at one scale affects sustainability at other scales, and it is understood that these processes are intertwined. Examples of such sustainability challenges range from air pollution to migration, technological change to conflict, and of concern to this thesis, to overfishing (see Norse et al., 2005). Whilst sustainability governance often remains abstract at a global scale, place remains fundamental because 'contribution to and outcome of any governance process can only meaningfully exist when it is specified for places' (Bush et al., 2015).

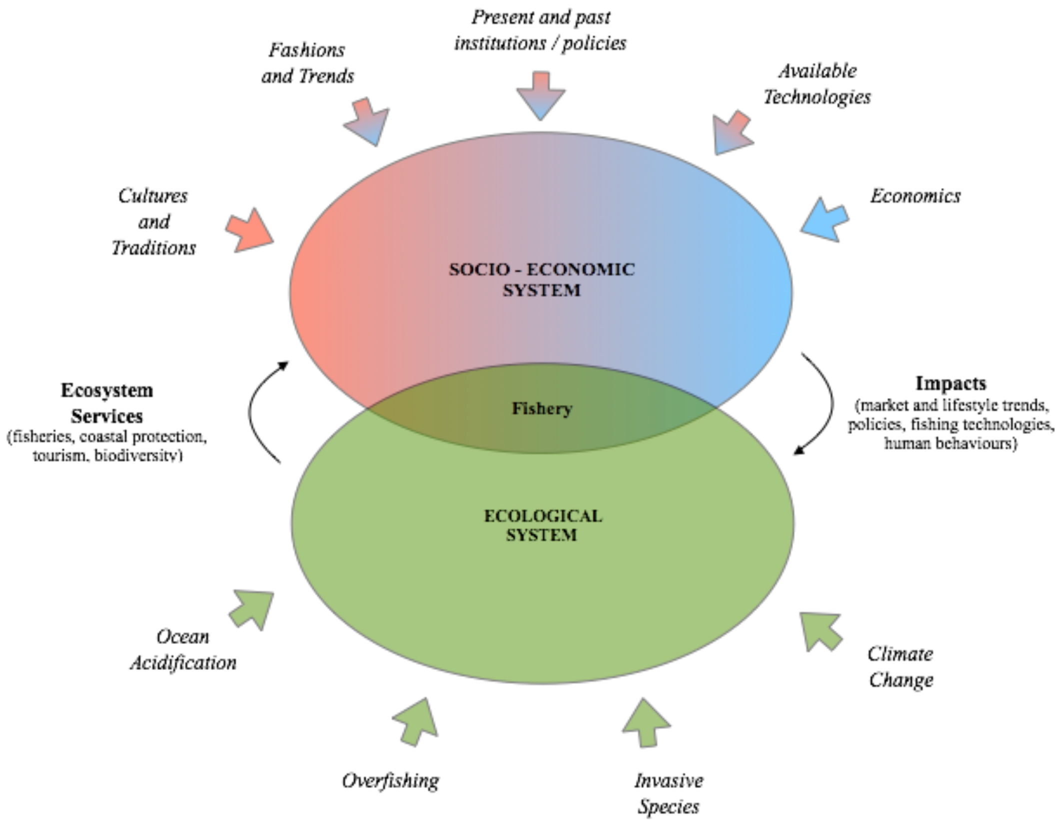


Figure 3. Coupled socio-ecological systems research places the social system and economic system as dependent upon the ecological system. Often the model recognises the feedback loops that operate between the socio-economic and ecological systems and the externalities that effect the coupled system overall.

Intuitively we understand that sustainability at the scale of the individual, or the local neighbourhood, is different from sustainability as a nation, or for the planet overall (Holling, 1995). Sense of place reflects processes by which individuals or groups identify, attach to, depend on, and modify places, as well as the meanings, values, and feelings that individuals or groups associate with a place (Chapin and Knapp, 2015). This context of place appears to have evolved 'a strange dichotomy' in academic research into sustainability governance (Bush et al., 2015). On the one hand, the role of place is largely ignored in studies on climate change, air quality, food sovereignty and food safety, where governing sustainability is framed as an abstract and placeless process, and where institutions and regimes are homogenous across geographical space (Lövbrand et al., 2009; Hulme, 2010;). On the other hand, localized place-based sustainability governance is often overemphasized (Lane and Corbett, 2005), and articulated in relation to local places with unique, concrete and contextualised notions and definitions of sustainability, and are used to 'refute the abstracting and homogenising effects of globalisation' (Bush et al., 2015).

Whilst this is evidence of an interconnected world, there is no "global market-*place*" for seafood produce; rather a set of globally connected 'market-*places*' and a business world not as "flat" as Thomas Friedman (2005) once predicted (that everybody, everywhere, is subject to the same forces of globalization). Indeed, distance still matters (Ghemawat, 2001), supply chains are still predominantly local, and most nations seafood markets are far from being integrated intra-nationally, let alone inter-nationally (Ghemawat, 2015).

Whilst scientists, governments and consumers may want order and consistency, the only way to ensure place relevant data is to localise, and not to standardise. All places are subject to their own social, ecological and economic conditions and each evolves at its own pace. Pankaj Ghemawat (2011) refers to this as "rooted cosmopolitanism" which, from a business studies perspective, refers to respecting and understanding each local economy and culture [socio-economic system] for its own strengths e.g. labour markets, regulatory and cultural environment; but equally, from a biological sciences perspective, could relate to respecting and understanding local habitat and ecosystem properties, such as stock maturity or habitat condition.

It is through this scalable and nuanced lens of place-based research, that the creation of the Municipality of Lipsi, as a potentially (more) sustainable place, is going to be articulated within this thesis. The sustainability of the Lipsi Small-Scale Fishery is therefore about ensuring the sustainable extraction and consumption of coastal fish species and the ecologically and culturally appropriate management of the fishery, the coastal habitats, and the associated species assemblages on which the community depends. Management solutions will focus on place-based solutions to reinvigorate and improve productivity (seafood supply) of the fishery so that it can be sustainably exploited by, and provide food security for, the local people, in perpetuity: A step towards sustainable place creation.

1.3 The Triple Bottom Line and Full Cost Accounting

Within the business and management literature there is a growing debate about what and how business leaders, managers and decision makers can contribute to a transition to an ecologically sustainable society (Porritt and Tang 2007; Jackson 2009; Milne and Gray, 2013). Here the 'three pillars of sustainability' form the basis for the now famous 'triple bottom line' (3BL) concept (Elkington, 1997). In its simplest terms, the 3BL agenda focuses businesses on the economic value they generate, and on the environmental and social value they add or subtract. It was developed in response to the view that the world's current dominant economic system – i.e. capitalism – is not delivering sustainable development in its current format (Bebbington and Gray, 2001; Jones et al., 2010).

Central to this changing philosophy is the promotion of "full cost accounting" FCA (also referred to as Environmental full-cost accounting (Epstein, 1996), or true-cost / total cost accounting (Centre for Waste Reduction Technologies, 1999). FCA, like life-cycle costing, cost-benefit analysis, balanced scorecard for sustainability and material flow cost accounting, is classified under the umbrella of Environmental Management Accounting (EMA) tools and systems (Jasch and Savage, 2008; Qian and Burritt, 2009). FCA is a method of cost accounting that traces direct costs and allocates indirect costs by presenting information about the possible environmental, social and economic (3BL) costs of a proposed business action.

In traditional cost accounting, the 'bottom line' refers to either the "profit" or "loss" of a business model and, derives is name from the fact that it is usually recorded at the bottom of a statement of revenue and expenses. Under the traditional cost accounting model, it is the economic system that is considered in isolation. Yet since the 1980s, social and environmental movements, combined with governmental adoption of the concept (e.g. The US Environmental Protection Agency) has brought this broader FCA definition into the public consciousness (Martinez-Alier, 2009; D'Onza et al., 2016).

Since the mid-1990s there been an increased popularity and adoption of the 3BL concept among business organisations (Glac, 2015) reflected in standards such as the International Organisation for Standardisation (ISO) standards for Corporate and Social Responsibility (ISO 26000) or Management Systems Auditing (IS019011). Of concern to this thesis are the development of sustainability standards and certification systems that focus on the creation of sustainable food systems (i.e. Reinecke et al. 2012). Here, industry standards referencing 3BL include global social brands such as Rainforest Alliance and Fairtrade, with many other organisations adopting the (3BL) framework to evaluate their performance into a broader perspective and to create greater business value (Slaper and Hall, 2011).

However, 3BL has come under scrutiny for a lack of specificity regarding the measurement of the social and environmental components (Milne and Gray 2012; Glac, 2015). It remains unclear to what extent, the adoption of the processes and rhetoric of the 3BL has any substantive influence on business behavior (Archel et al. 2008; Milne and Gray, 2012). The difficulty of finding a unified measure for the two additional bottom lines has been considered a fundamental threat to the 3BL idea, which implies a final result expressed in some unit of measurement.

Despite the criticism, the debate in the literature is increasingly coalescing around a view of 3BL as a paradigm of sustainable business practice rather than a specific approach to performance measurement or accounting (Glac, 2015). Either way, the 3BL has enabled organisations to take a more holistic view of their business models and to start to evaluate the future consequences of any decisions taken (Slaper and Hall, 2011).

The evolution in both socio-ecological science and business management thinking has brought the temporal aspect of sustainability into focus. Taking the long view has been championed as the central principal of sustainability relating to long-term viability and intergenerational aspects of sustainable development (Held, 2001). The temporal dimension represents a core area of potential trade-offs for management and business behaviour – "You can't have your cake and eat it" (Hahn et al., 2010).

This degradation of the worlds ecological systems is an issue highlighted by the Millennium Ecosystem Assessment (MEA), a major assessment of the human impact on the environment published in 2005. The Millennium Ecosystem Assessment (2005) found that human actions have been depleting natural capital and depleting it to the extent that the ability of ecosystems to sustain future generations can no longer be taken for granted.

Since this landmark assessment, there have been efforts to extend the 3BL concept, to create 'four pillars of sustainability' or a 'quadruple bottom line' (Waite, 2013). Here, the fourth pillar denotes a future-oriented approach; articulating the requirements for intergenerational equality, highlighting the problems identified in the Capital Stock Model of over-consumption of natural capital today reducing interest accruing tomorrow (weak versus strong sustainability) (Diets and Neumayer 2007).

Although temporal discounting matters in making individual choices; e.g. the economics of overexploitation (Clark, 1973), the extent of temporal discounting is poorly understood in a group setting (Jacquet et al. 2013). Despite this, an inter-generational consideration has already found favour pertaining to global issues relating to climate change (Schelling, 1995, Jacquet et al, 2013) and of particular note to this thesis, to global overfishing from capture fisheries (Sumalia and Walters, 2005). Capture Fisheries are those fisheries where the harvesting of aquatic resources and production is done in the wild (FAO, 2016). By contrast Aquaculture is the harvesting of aquatic resources and production from a controlled environment (FAO, 2016).

Capture Fisheries currently represent the only large-scale food production system based on a wild resource and, as such, have their own set of environmental challenges regarding sustainability. These include exploitation levels of target and by-catch species and ecosystem impacts (Ziegler et al., 2016). Sustainability assessments by fisheries managers have so far focused on these fishery-specific aspects but left out the wider environmental impacts of fishing activities and have failed to challenge the sustainability of the fishing process at each stage of the supply chain. Therefore:

"If the goal of fisheries management is to maximize societal values generated from limited marine living resources, with minimized environmental impacts and in a way that can be sustained indefinitely (which, in our view, should be its main goal), recognizing and taking into account the product perspective is necessary".

(Ziegler et al., 2016)

1.4 Life Cycle Assessment and Sustainable Supply Chain Management

There is a current call (Ziegler et al., 2016) to expand the concept of sustainable seafood through the use of the Life Cycle Assessment (LCA) (Figure 4). This call parallels the increased attention given to seafood products and supply chains as witnessed by the rapid rise of seafood certification and other consumer guidance initiatives (Pelletier and Tyedmers, 2008; Agnew et al., 2014).

LCA is a standardized framework used to quantify resource use and a broad suite of environmental impacts of products through their supply chains (ISO 2006a; ISO 2006b) and has gained widespread recognition and use in other sectors of industry and policy (European Commission, 2003, Finnveden et al. 2009). LCA studies already exist for key resources such as oil (Epstein et al., 2002) and coal (Epstein et al., 2011), and have been conducted to rigorously examine the many stages in the life cycle of a resource, including environmental externalities, or "hidden costs."

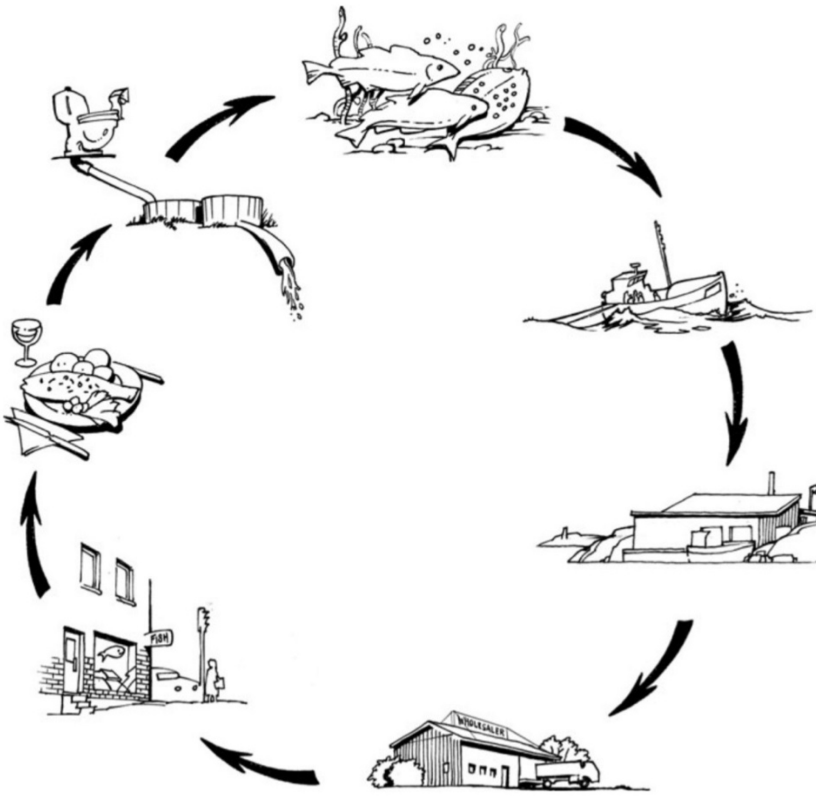


Figure 4. Expanding the concept of sustainable seafood using the Life Cycle Assessment (from Ziegler et al., 2016). A stylized life cycle of seafood production (illustration Jürgen Asp).

Externalities occur when the activity of one agent affects the well-being of another agent outside of market mechanisms. They are often not considered in decision making leading to distorted decision-making processes and reduced societal welfare (National Research Council, 2012). A significant barrier to the successful implementation of LCA is lack of full fishery supply chain data. Indeed, it has been described as "the overarching challenge" to obtain sufficiently representative and precise data (Ziegler et al., 2016). As such, an approach is needed which captures each life cycle stage of a fisheries product and explores both the supply side and demand side drivers of a given capture fishery supply chain.

Supply Chain Management (SCM) is the management of material and information flows (Thomas and Griffin, 1996) and provides a simple, coherent and logical framework around which to articulate the sustainability (or otherwise) of a fishery supply chain. Global supply chains have been played a significant part of natural resource degradation, as they are one of the 'principal means' through which manufactured capital displaces natural capital (Matthews et al., 2016). However, (SCM) or Sustainable Supply Chain Management (SSCM) also has the potential to be a "locus for much of the change towards sustainability and make important contributions to the sustainability of the broader ecosystems" (Mohrman and Worley, 2010). Contemporary theories of sustainability (Matthews et al., 2016) and novel instrumental logics (Montabon et al., 2016) are providing clarity and a coherent research direction in the field of SSCM. It is currently proposed that transdisciplinary studies can further our progress since:

"natural sciences can provide objective ecological metrics to assess the environmental effectiveness of current SSCM initiatives"

Matthews et al. (2016).

Furthermore, if an 'Ecologically Dominant' logic can inform SSCM initiatives and shift the focus from the instrumental logic that asks *how can a supply chain benefit from addressing environmental or social issues?* (Gao & Bansal, 2013; Garriga & Melé, 2004) to the ACTUAL question of *how can a supply chain become sustainable*? (Montaban et al., 2016), then genuine progress towards sustainable supply chains may become a reality.

In this thesis, SSCM will focus on the broad stages of the supply chain of a small scale coastal fishery. This theoretical construct includes the 'Habitat' that equates to a traditional supplier, and then Assemblage, Fishery, and Market that forms the 'Internal Supply Chain' of the small-scale fishery 'business'. Finally, consumers, like in other conventional supply chains mark the end-point for the fisheries' products (Figure 5). This novel approach can be seen as reflecting the deficiency of data available to LCA researchers (Ziegler et al., 2016) through the deliberate collection of data under a supply chain format. LCA is typically limited to considering environmental impacts and excludes assessment of other relevant social and economic impacts. However, by locating the supply chain within a coupled-socio ecological system in the context of 'place', it is proposed that a richer (ecological, economic and social) understanding of fishery supply chain sustainability will be achieved, allowing more relevant and appropriate management initiatives to be generated.

Research which aims to integrate all three pillars of sustainability in one single LCA method (i.e. Valdivia et al., 2013; Zamagni et al. 2013), faces challenges due to social indicators that are non-linear, descriptive and with less clarity as to what ‘desirable’ is (Zieglar et al., 2016). Despite these challenges there is some interesting preliminary work that advances this field in seafood production (e.g. Kruse et al., 2009; Veldhuizen et al., 2014; Veldhuizen et al., 2015).

This thesis contributes to this field by promoting transdisciplinary (place-based / coupled socio-ecological system / supply chain) research offering a logical, ‘step by step’ approach (supply chain management) to capturing both the relevant environmental aspects of seafood product extraction (ecological system) and its influence on, and by, the consumer and the marketplace (socio-economic system). Critically, this framework is articulated at the level of ‘place’, offering a scalable framework from which to articulate a given fishery’s perceived ‘sustainability’.

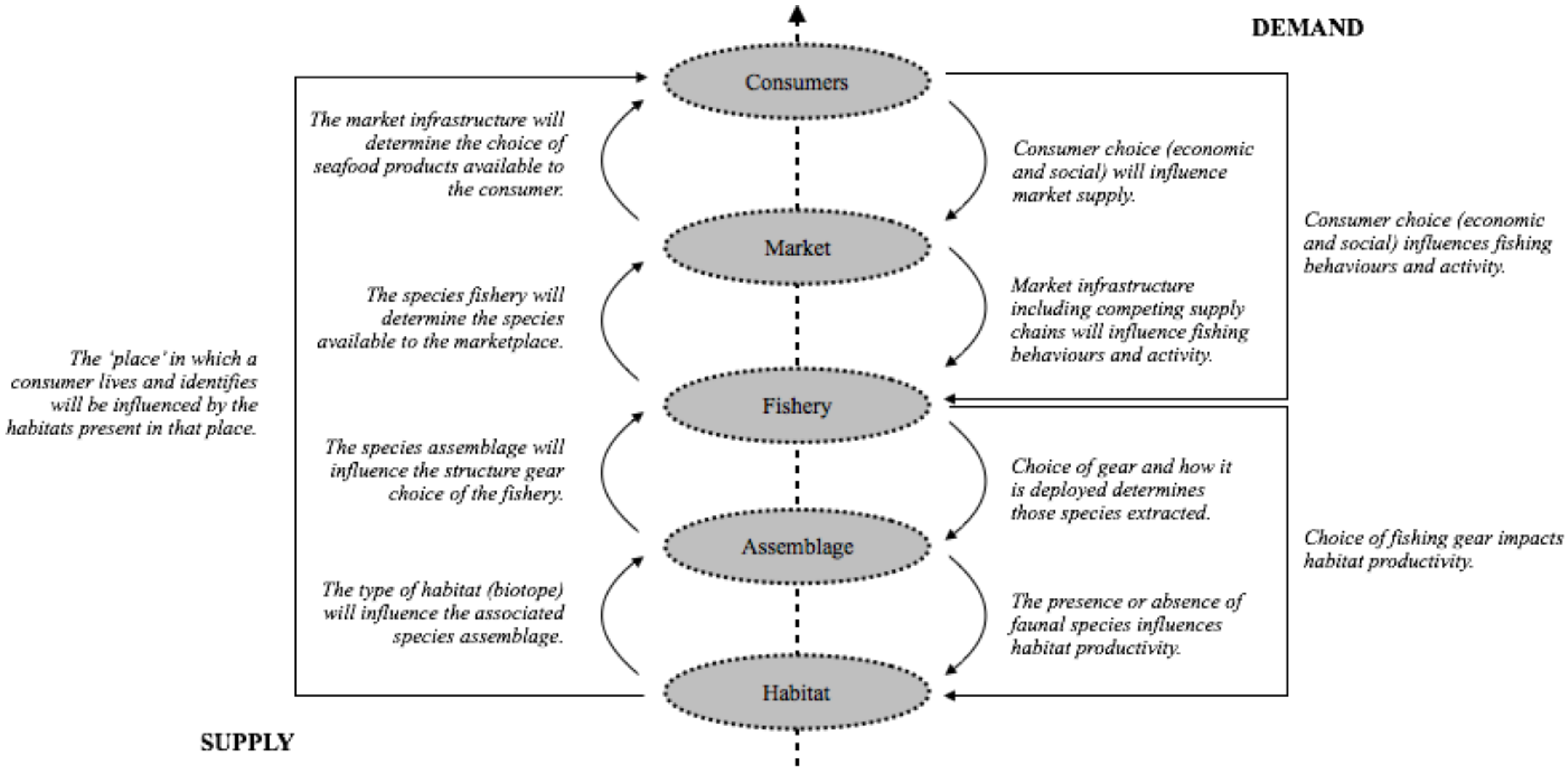


Figure 5. A conceptualisation of a Small-Scale Capture Fishery supply chain as a research framework for Sustainable Supply Chain Management

1.5 Methods for Intergrating Place-based thinking into Sustainable Supply Chain Management

From a Small-Scale Capture Fisheries (SSCF) supply chain perspective, socio-ecological system resilience is localised and place-specific (Béné et al, 2016). This thesis contends that the rich and detailed data collection to inform sustainable supply chain management (hereafter SSCM) at the local level, is the best way to subsequently inform sustainability initiatives at the regional and the global. Scientists have already cautioned that traditional public spheres for tackling environmental issues can act to close-down deliberation and marginalise informal knowledge, especially where institutions retain norms that emphasise abstract, placeless evidence (MacGillivray and Franklin, 2015). Comparisons between local fishery supply chains is only appropriate through the informed aggregation of local data trends into broader spatial units and patterns (Figure 6).

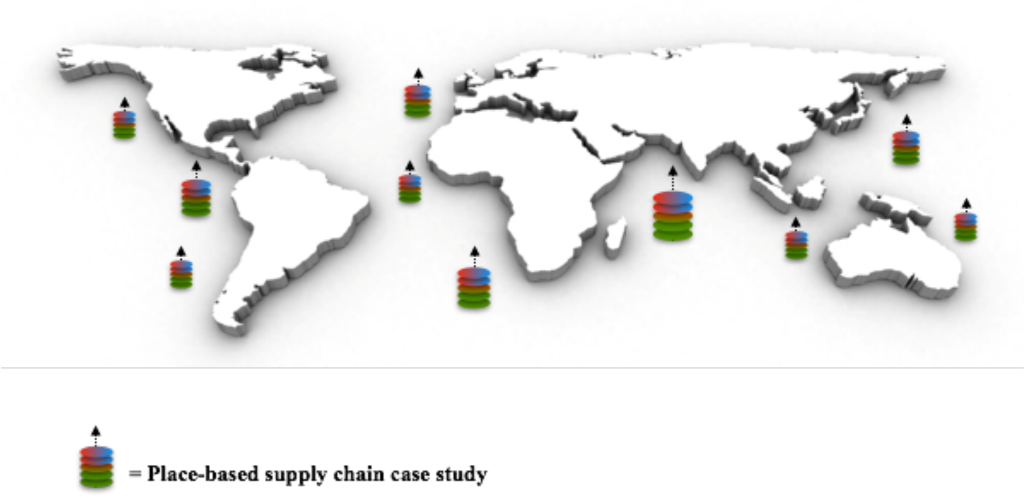


Figure 6. To fully understand the global supply chain from capture fisheries requires a range of local place-based case studies at spatial scales appropriate to place.

This is a bottom up, place-based perspective on sustainable supply chain management in contrast to the global change literature where global processes are downscaled to assess their impacts at the local level. However, regardless of whether one is downscaling or aggregating, there is considerable consensus about those attributes, characteristics and practices that influence the sustainability of a

Small-Scale Capture Fisheries supply chain. For example, an intact habitat offers greater resilience than a degraded one in the face of overfishing.

In addition to scale, temporal variability must be considered when defining the ecological baseline of the supply chain. This is to avoid 'shifting baselines' (Pauly et al, 1995) in our appraisal of supply chain sustainability. The rates of onset of overfishing are measured in years, decades and centuries (Jackson et al., 2001) and that ecological resilience considered at these temporal scales cannot be separated from historic social processes is a confounding issue in resilience thinking (Cutter et al, 2008) (Figure 7).

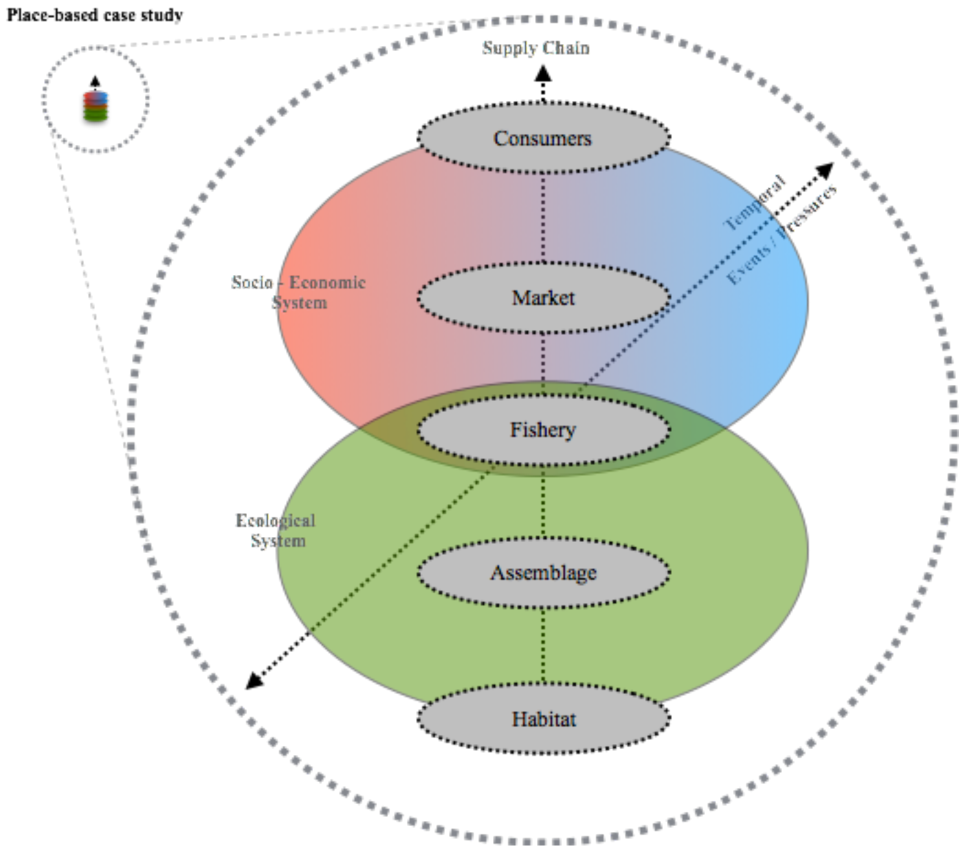


Figure 7. Place-based studies into supply chains need to consider both the scale and unit of analysis, and temporal variability. Supply chain case studies can provide comparisons across systems if ecological baselines are made explicit.

This thesis proposes a place-based model for understanding supply chains at the local level. Ecological and socio-economic systems are interconnected and thus separation is arbitrary. However, human actions (the fishery) impact the state of the ecological system, and thus cannot be ignored, since they in turn affect the resilience of the socio-economic system.

This thesis has been deliberately structured into 5 ‘Results’ chapters, or specifcally one chapter dedicated to each of the five ‘stages’ in the conceptual framework outlined in Figure 7 e.g. Chapter 5 for Habitat, Chapter 6 for Assemblage, Chapter 7 for Fishery, Chapter 8 for Market and Chapter 9 for Consumer. In many respects, each chapter is a self containted study, but they have been presented in a logical manner which follows the conceptual framework outlined in Chapter 4. Each chapter will cover the specific methods utilised to explore the stage in more detail (see Table 1 below), and in each chapter the results will be presented with a subsequent discussion. Finally, in Chapter 10, a holistic analysis of all five stages provides an overall picture of the future sustainability of the supply chain, with a section on the management recommendations proposed that could help ensure the future resilience of the supply chain.

The sustainable supply chain framework presented herein articulates resilience as both an inherent condition and as a process (Lengnick-Hall and Beck, 2005; Plummer and Armitage; 2007). The sustainability of the supply chain must be seen as a snapshot in time (a static state) in need of regular review, but temporal processes are embedded within the model to articulate the dynamic nature of the framework. Whilst this sustainable supply chain framework is a conceptual model, it must be recognized that exogenous factors such as national and supra-national policies will exert influence on the supply chain locally. As with all case studies, the conclusions drawn, and recommendations made are unique to this place at this time. Case studies such as this cannot be truly replicated, and therefore corroborated, and yet the strength of any case study is the often the great detail and in-depth knowledge of the subject that can be achieved from such a study. The weaknesses associated with case studies are well known, not least elements relating to researcher bias, where it is possible for the author to form a bias which shapes the subject of the study, the form of data collecition, or the way that the data is interpreted. That said, Flyvbjerg (2006) makes the point that both human and natural sciences can be advanced by a single case study which is a philosophy embraced by this thesis.

1.6 Research Philosophy

The research methods adopted here have been adopted because they are grounded in a sound research philosophy. In any research undertaken, it is crucial that the decisions of 'what' and 'how' to research are founded on a research design that is coherent, clear and logical in its approach. In this thesis, research choices pertaining to the ontological position have gone on to inform the epistemological position, and literature review of extant theory has in turn informed the research questions, aims and objectives. The importance of systematic, logical, and robust research cannot be underestimated. Indeed, the difference between a scientific observation and a layperson's observation is that the first is done systematically; it is based on logic, and not just beliefs (Ghauri and Grønhaug, 2005).

"*The observer must be independent"* and *"the researcher's human interests should be irrelevant"*

Easterby-Smith et al, 2012.

Through adopting this philosophy, choices were made clearly and consistently using 'the research onion' (Saunders et al, 2009) allowing a consistent and informed approach to underpin the design process (Figure 8). Whilst this was an aspirational objective for a researcher, it must also be acknowledged that the amount of description, analysis, or summary material that is provided is ultimately up to the author (see Stake, 2007), and therefore as the researcher it has to be decided:

1. How much to make the report a story.
2. How much to compare with other cases.
3. How much to formalize generalizations or leave such generalizing to readers.
4. How much description of the researcher to include in the report.
5. Whether or not and how much to protect anonymity.

The research design will be stated as rooted in a post-positivist philosophy, but the reality of this research si that the approach to data gathering might deviate from this philosophy as appropriate to the research at each stage of the supply chain.

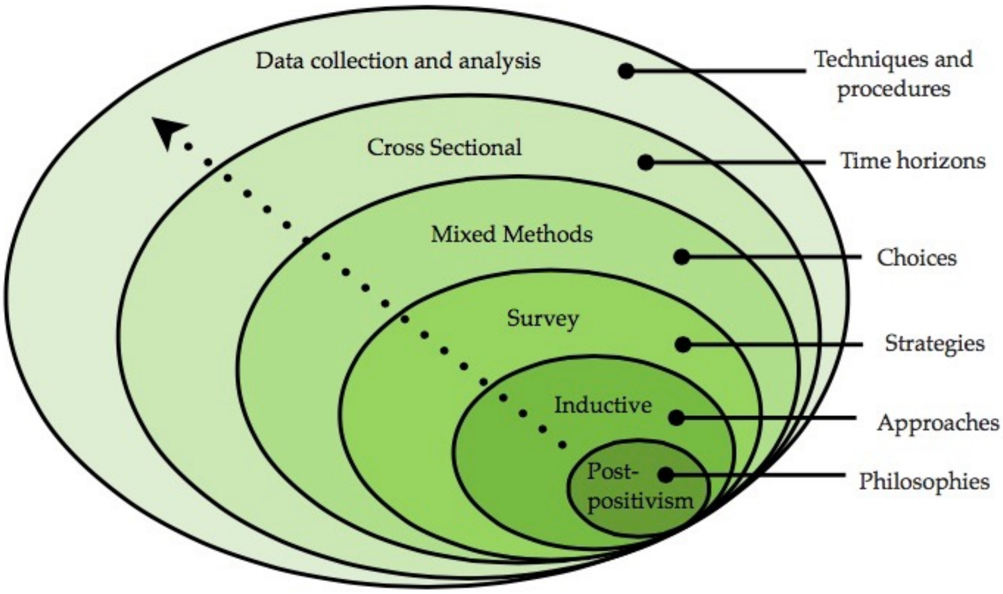


Figure 8. The research onion adapted from Saunders et al (2009). It is crucial that the research design follows a consistent and informed approach whereby the ontological informs the epistemological, and review of extant theory informs the research questions.

The research process has been grounded ontologically in an objective reality, taking a ‘post-positivist’ approach to the logic of discovery. While positivists believe that the researcher and the researched person are independent of each other, post-positivists accept that theories, background, knowledge and values of the researcher can influence what is observed (Robson, 2016). Such an epistemological position demands that the subject of the research should be measured via objective methods, rather than subjectively (Remenyi et al, 1998). The major assumption underpinning this position is that reality exists and can be measured, rooting this epistemological stance in a dualist interpretation of the form and nature of reality; there is an independent researcher and subject to be researched. Essentially this is the belief that there is a ‘real world’ that exists, independent of our interpretation of it. Inductive reasoning guided the research whereby general propositions (Greek seagrass meadows are important habitats for food security) were derived from specific place-based examples (Rhodes’ seagrass meadows are important for its food security). Induction in this way is based on empirical evidence (Ghauri and Grønhaug, 2005), and explanation is derived from a well-attested data set (a ‘valid’ sample, in this case Stefan Kalogirou’s (2011) PhD Thesis). In this example, the process of systematic data collection provides the basis for the induction of theory, with knowledge subsequently improved by searching for associations between variables, collecting data and comparing the probability to that of a chance outcome.

Through adopting a mixed-methods approach to data collection to assess supply chains of fish from coastal habitat to catch, and from catch to market, allows for a more comprehensive understanding of the social, ecological and economic factors that drive fishery exploitation. In this thesis this is achieved by assessing habitat distribution and integrity (what habitats exist and how 'healthy' they are - Chapter 5); species assemblage composition (what species live where and when - Chapter 6); catch composition and catch production (what species are fished and where from – Chapter 7); market infrastructure and seafood supply (what fish are available and where from Chapter 8) and assessing consumer choice (what species are consumed and why – Chapter 9). A major advantage of using mixed-methods over mono-methods is that triangulation can take place (Saunders et al, 2009).

Triangulation will be conducted when interrogating each stage of the supply chain (Figure 9) and can be described as a combination of two or more research methodologies in the study of the same phenomenon (Bogdan and Biklen, 2006). Through adopting this approach some of the intrinsic biases and weaknesses inherent in mono-method studies (Jack and Raturi, 2006) are addressed through the empirical data collected.

Data collection took the form of *in-situ* surveys that allowed for the collection of large amounts of data in an efficient and economical way. Surveys also facilitated the collection of quantitative data, enabling the use of descriptive and inferential statistics to formulate reasoned relationships between variables. However, a suite of anecdotal evidence and qualitative data also supported this quantitative data. Sampling methods in this way can generate findings representative of whole populations (Saunders et al, 2009) supporting in turn extrapolation of findings. Cross sectional research design was chosen to investigate place-based socio-ecological systems in Lipsi, Greece. Fieldwork took place in 2014/2015 over the four meteorological calendar seasons (Winter = December, January, February, Spring = March, April, May, Summer = June, July, August, and Autumn = September, October, November).

The research philosophy outlined above is appropriate to this type of reseach since it is essentially a 'case-study', even though it is being approached in a transdisciplinary manner. Whilst there are, of coure, other philosophies and approaches that could also be justified, it is my belief that pursuing this approach is appropriate to this particular study because:

First, there is a long history of postitivism and post-positivism in the Natural Sciences allows this work to contribute to discussions in this field in a logical manner; and second, as articulated in this chapter, it is the position of this thesis that the 'sustainability' of both the economic and social systems are fundamentally dependent on the sustainability of the ecological system. As ecologists, the post-positivist approach is 'de facto' and therefore this approach gives weigth to the results collected in chapters 5 and 6 that form the platform for this conceptualisation of the supply chain.

Of course the choice to conduct a case study can also be challenged. Indeed, all research designs can be discussed in terms of their relative strengths and limitations. The merits of choosing to conduct a case study for the Lipsi fishery are inherently related to the rationale for selecting it as the most appropriate plan for investigating the seafood supply chain. This case study offers a means of investing a complex system, consisting of multiple varibales that are all important in the understanding of a'real life' phenomenton. The flip-side to this is of course that since it is a case study, which focuses on a single 'place', the issue of generalisability is brought sharply into focus.

In a paper by Flyvbjerg (2006) five "misunderstandings" about case study research were articulated that relate closely to the perceived stengths and weaknesses of this thesis. Flyberg states these "misunderstandings" and dismantles them, following up by substituting a more accurate statement about the issue underlying each misunderstanding. These misunderstandings and their restatements are displayed in Table 3.1.

Table 1 –Five Misunderstandings about case-study research. Adapted from Flybergs (2006)

Misunderstanding	Restatement
General knowledge is more valuable than context-specific knowledge.	Universals can't be found in the study of human affairs. Context dependent knowledge is more valuable.
One can't generalize from a single case, so a single case doesn't add to scientific development.	Formal generalization is overvalued as a source of scientific development; the force of a single example is underestimated
The case study is most useful in the first phase of a research process; used for generating hypotheses.	The case study is useful for both generating and testing of hypotheses but is not limited to these activities.
The case study confirms the researcher's preconceived notions.	There is no greater bias in case study toward confirming preconceived notions than in other forms of research.
It is difficult to summarize case studies into general propositions and theories.	Difficulty in summarizing case studies is due to properties of the reality studied, not the research method

If anything, the discussion in this section just highlights the challenges of attempting to do transdiciplanry research in a real-world context. Challenges during my time on Lipsi were not limited purely to academic dilemmas, but to the daily decisions that needed to be made regarding relationships, access to food and water, emotional and physical well-being, and above all safety. In such a context, the research that was conducted had to be the best it could be, whilst ensuring the smooth running of a marine research base, providing support and guidance for undergraduate and post-graduate students, and liasing with both a local NGO and the local community.

Compromises between the 'ideal' and the 'possible' were many, and therefore this thesis represents an inevitable compromise between the idealistc research design presented on paper, and the inevitable reality that comes with research in the field.

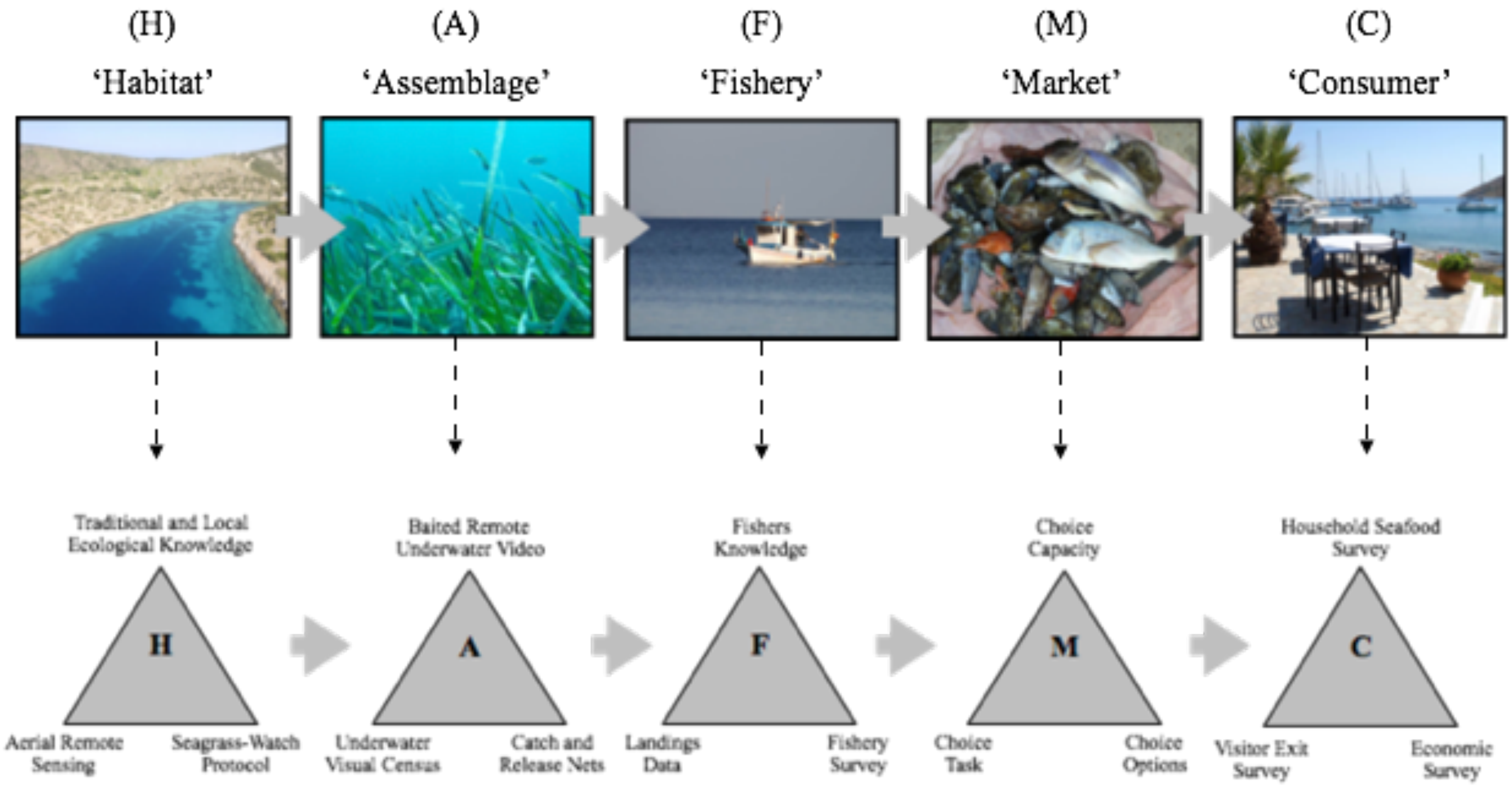


Figure 9. For a richer understanding of the 'Habitat to Consumer' Small-Scale Capture Fishery supply chain, three research elements were pursued at each stage of the supply chain (triangulation; (H) = Habitat, (A) = Assemblage, (F) = Fishery, (M) = Market & (C) Consumer

Table 2 - The main research questions (and sub research questions) relating to each of the five stages (Habitat, Assemblage, Fishery, Marketplace and Consumer) of the 'Habitat to Consumer' supply chain conceptual framework. The table includes key themes or contemporary theories from the literature and a summary of the key methods used to explore the supply chain.

Main research questions	Sub research questions covered in chapters 5-9	Themes from literature / contemporary theory	Methods
Q1. What are the **habitats** found in the coastal seascape of Lipsi Island?	Q1a. What are the coastal habitats around Lipsi? Q1b. What is the relative extent and distribution of habitats in the seascape? Q1c. What is the biological health of the habitats?	Habitat mapping through local knowledge (*e.g. Teixeira et al., 2013)* Habitat mapping using small-scale Unmanned Aerial Vehicles *(e.g. Barrell and Grant, 2015)* Importance of knowing habitat extent / Fragmentation *(e.g. Roelfsema et al., 2014)* Importance of understanding habitat connectivity / habitat mosaics *(e.g. Nagelkerken et al., 2015)* Habitat resilience relating to biological conditon *(e.g. Unsworth et al., 2015)* Defining habitats for spatial management *(e.g. Giakoumi et al., 2011)*	**1. Traditional and Local Ecological Knowledge** Interviews with 3 Lipsi fishers to establish both a local habitat typology and an initial habitat map of the coastal zone at the island scale (~150km^2). **2. Aerial Remote Sensing** Flights over 9 bays around Lipsi using an Unmaned Aerial Vehicle. This is to create photo orthomosaics and to establish habitat distribution at the bay scale. **3. Seagrass-Watch Protocol** Four seasons of Seagrass-Watch at the same 9 bays around Lipsi. This is to establish in-situ habitat observations pertaining to biological health at the site scale (33 quadrats per site).
Q2. What are the species **assemblages** associated with the coastal habitats around Lipsi**?**	Q2a. What is the abundance and diversity of species present in the coastal habitats? Q2b. How connected is the seascape i.e. is there species overlap between habitats?	Supply side variability in fish provisioning due to environmental factors. *(e.g. Harmelin-Vivien, 1994)* Ecosystem Service Providers and Fisheries Provisioning *(e.g. Manson et al., 2005)* Ecological Associations and habitat-linked Species	**1. Baited Remote Underwater Video** 432 deployments of Baited Remote Underwater Video stations (60-minute deployments) over four seasons (n = 108 per season) to establish ecological associations. **2. Underwater Visual Census** 432 Undewater Visual Census Apnea Point Count (10-minute surveys) over four seasons (n = 108 per season) to establish

	Q2c. What is the age and trophic structure of the species assemblage i.e. juvenile or adult individuals? Carnivores or herbivores?	*(Guidetti, 2000)* The importance of connectivity between coastal habitats *(e.g. Mumby et al., 2004)* Documenting fish utilisation of multiple coastal habitats *(e.g. Boström et al., 2011)* Food Web Interactions and positive or negative feedbacks *(e.g. Hamilton and Caselle, 2015)* Evidencing of the nursery role hypothesis *(e.g. Beck et al., 2001)*	ecological associations and individual species life history parameters (e.g. juvenile or adult). 432 Undewater Visual Census Apnea Belt Transect (10-minute surveys) over four seasons (n = 108 per season) to establish ecological associations and individual species life history parameters (e.g. juvenile or adult) **3. Catch and Release Nets** 486 Fyke Net deployments of ~12hrs each (~5,832hrs in total) over four seasons (~1458hrs per season) to establish ecological associations and individual species life history parameters (e.g. juvenile or adult). 324 Minnow Net deployments of ~12hrs each (~3,888hrs in total) over four seasons (~972hrs per season) to establish ecological associations and individual species life history parameters (e.g. juvenile or adult).
Q3. How do you characterise the Lipsi **fishery?**	Q3a. How, when and where are species extracted by the Lipsi fishery? Q3b. What species are being fished in the fishery? Q3c. What are the longer-term trends in species diversity and abundance as recalled by local fishers?	Local stock assessment / Habitat associations *(e.g. Kalogirou et al, 2010)* Complexity of multi-species multi-gear fisheries *(e.g. Tzanatos et al, 2005)* The importance of understanding the behavioural dynamics of fishers *(e.g. Salas and Gaertner, 2004)* Harnessing Fishers Ecological Knowledge / Fishers Perceptions *(e.g. Coll et al, 2014)* Impact of fisheries on habitat integrity *(e.g. Puig et al., 2012)* Ecosystem Based Fisheries Management *(e.g. Moore e tal., 2009)*	**1. Reported Fishing Effort** 139 surveys over 3 seasons (41 in Spring, 59 in Summer and 39 in Autumn) to establish patterns of fishing effort relating to seasonal gear use, extraction patterns, habitat associaitons and fishing locations / sites) 2. **Fishery Landings Data** 139 surveys over 3 seasons (41 in Spring, 59 in Summer and 39 in Autumn) to establish data relating to catch abundance / frequency of specie and to life-history parameters (e.g. stock maturity and trophic level). **3. Fisheres Ecological Knowledge** Semi-structured interviews with 7 full-time fishers from Lipsi to establish temporal and spatial changes in seafood supply. The interviews are also an opportunity for the fishes to suggest management measures.

Q4. What constitutes the **marketplace** for seafood products?	Q4a. What is the market infrastructure / seafood retailers available to the people of Lipsi? Q4b. What seafood products are available at market to purchase? Q4c. How are those seafood products that are available being presented to the consumer?	Exploring how small-scale fisheries contribute to food security and poverty reduction (e.g. Béné et al., 2016). The supermarketisation of the marketplace and the growth in the number of imported species. *(e.g. Cohen et al., 2013)* Investigating how the tools of choice architecture are present in seafood products, *(e.g Sunstein and Reisch, 2014)* Exploring the seafood products options presented to consumers *(e.g. Stamatis et al., 2005)*	**1. Choice Capacity Mapping** During a 'snapshot' survey in August 2014 the number, type and size of retailers were identified, counted and geographically located to establish 'Choice Capacity'. This is to establish the locations and retail infrastructure for selling seafood products. **2. Choice Task Survey** During a 'snapshot' survey in August 2014 diversity of species available to the consumer at market and record their place of origin was recorded. This is to establish the 'Choice Task' presented to consumers and the presence of imported species. **3. Choice Options Survey** During a 'snapshot' survey in August 2014 the manner of product presentation (e.g. frozen, canned etc) was recorded to establish 'Choice Options' and products presented to consumers.
Q5. What is driving the **consumption** of seafood products?	Q5a. What are the seafood products consumed on Lipsi? Q5b. Is demand for species different between particular social groups? Q5c. Do some species of fish cost more than others?	The changing nature of seafood product supply and the proliferation of invasive species *(e.g. Zeneteos et al., 2008)* The increasing diversity and amount of food that is imported for tourist consumption. *(e.g. Telfer and Wall, 1996)* Evolving relations between food, place and identity *(e.g. Erkus-Öztürk and Terhost, 2016)* The growth and development of 'food tourism' *(e.g. Everett and Aitchinson, 2008)* Economic considerations determining supply chain parameters *(e.g. Casson, 2013)*	**1. Visitor Exit Survey** Visitor Exit Surveys were conducted with 723 individuals between March and November 2014 to establish consumer demographics and seafood consumption patterns. **2. Household Survey** Residents of Lipsi participated in 123 household surveys between March and November 2014 to establish seafood consumption preferences and patterns. **3. Economic Survey** Continiuous monitoring of the 'price per kilo' of seafood products was conducted between March and November 2014. This was to establish prices for different seafood species.

1.7 Contribution

This thesis makes several novel theoretical, methodological and practical contributions. These contributions are articulated here:

Theoretical contribution: Within this thesis, the Supply Chain Management concept has been utilised in a novel way by embedding a supply chain into a coupled Socio-Ecological System (Figure 10).

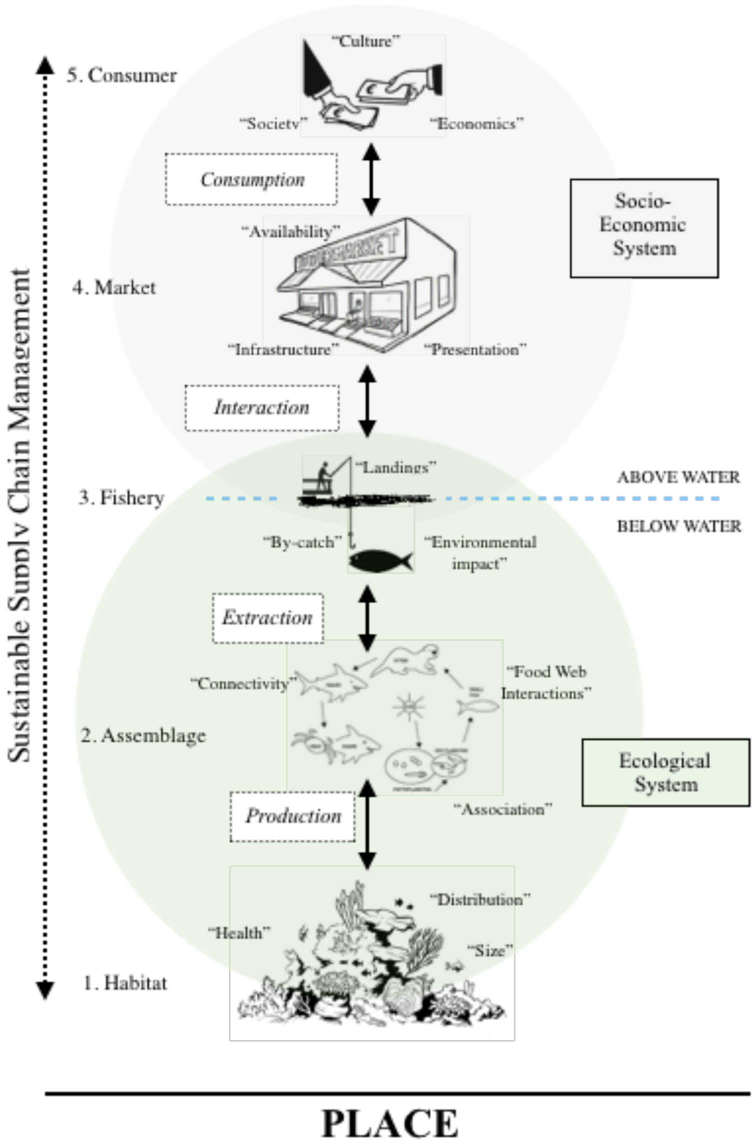


Figure 10 – Sustainable Supply Chain Management theory has been embedded into Place-based Socio-Ecological Systems thinking with the Fishery 'stage' acting as the confluence of the two systems.

As such, this conceptual model for Sustainable Supply Chain Management enables the explicit focus on the sustainability of a ‘place’, with the habitat conceptualised as the supplier needing to meet the demand of the consumer. Through this model, the supply-side and demand-side elements of the supply chain can also be articulated using the positive and negative feedback terminology more common to the Socio-Ecological Systems literature.

Critically, and a fundamental driver for the development of this model, is that ‘supply chains’ are much more intuitive to local stakeholders than coupled socio-ecological systems, and as such there was a wish to find a medium through which place-based socio-ecological systems thinking could be articulated in a more accessible manner.

This thesis has focused on each of the five stages ‘Habitat’, ‘Assemblage’, ‘Fishery’, ‘Market’ and ‘Consumer’, but there is scope for further research that more deeplu explores the relationships between supply chain stages – namely the ‘production’ of the product by the habitat, the means of ‘extraction’ of the product , the ‘interaction’ of the product with others in the marketplace and the manner in which ‘consumption’ of the product occurs.

Methodological contribution: This thesis is the first transdisciplinary attempt (hopefully of many!) to combine methods from the natural and social sciences. It was conducted in a such a way to remain true to the spirit of the ESRC research funding which was awarded to the Cardiff Buisness School, but also to the Sustainable Places Research Institute, and to the project’s conception which is firmly rooted in Marine Ecology.

For this reason, the reader might find either security, or discomfort, in reading the methods employed for each research in each chapter depending upon their own episemelogical and ontological position. The point has already been made that Sustainability Science defines itself by the problems it addresses rather than by the disciplines it employs and that is certainly true if this thesis. The holistic overview of the entire supply chain (the life-cycle of the seafood product) is a genuine first attempt (to my knowledge) to move away from the black-box thinking of the ocean as a homogenous entity (“catch to market” thinking), but equally, as an marine ecologist, an attempt to explore the drivers of ecological change through a lens that considers the impact of consumers and society.

Finally, there are a couple of other novel contributions within this thesis, not least the the novel use of lightweight aerial drones for mapping coastal ecosystems (an emerging theme in coastal research) and the use of breath-hold ‘apnea’ freediving techniques in an attemot to improve the accuracy of existing UVC techniques.

The practical contributions of this thesis will be discussed in the final chapter.

CHAPTER 2 – Research Need

2.1 Thinking global

In the final report of the Global Ocean Commission (2014), the authors warn in their introductory letter:

"Our ocean is in decline. Habitat destruction, biodiversity loss, overfishing, pollution, climate change and ocean acidification are pushing the ocean system to the point of collapse. Governance is woefully inadequate, and on the high seas, anarchy rules the waves. Technological advance, combined with a lack of regulation, is widening the gap between rich and poor as those countries that can, exploit dwindling resources while those that can't experience the consequences of those actions. Regional stability, food security, climate resilience, and our children's future are all under threat" (p. 3).

Whilst there is some disagreement between marine biologists over exactly how bad things have become, there is little disagreement that there needs to be a sea-change in the way we approach fishing and fisheries management as we transition towards resource sustainability. Brown et al (2013) notes that the globally small, but locally significant stressors such as oil pollution and habitat loss are now much more common, and are acting synergistically with global "mega-stressors" that include a growing world population, a warming and acidifying ocean, and of concern to this thesis, the chronic overfishing that is leading to wholescale ecological system change (Worm et al. 2006).

Since the 1950's, global fisheries have gone through a series of unprecedented changes (Pauly, 1995; Jackson et al, 2001; Pauly et al., 2005; Worm et al., 2006; Worm et al., 2009; Jackson 2010), with a 2.4-fold increase in yield being achieved through a 4-fold expansion in the fishing area (Swartz et al. 2010). Modern fisheries have expanded their range to operate further offshore, and at greater depths than ever before (Norse et al, 2012, Watson et al, 2015), to reach a record catch of 78.4

million tonnes in 2014 (after excluding highly variable anchoveta) (FAO, 2016) (Figure 10).

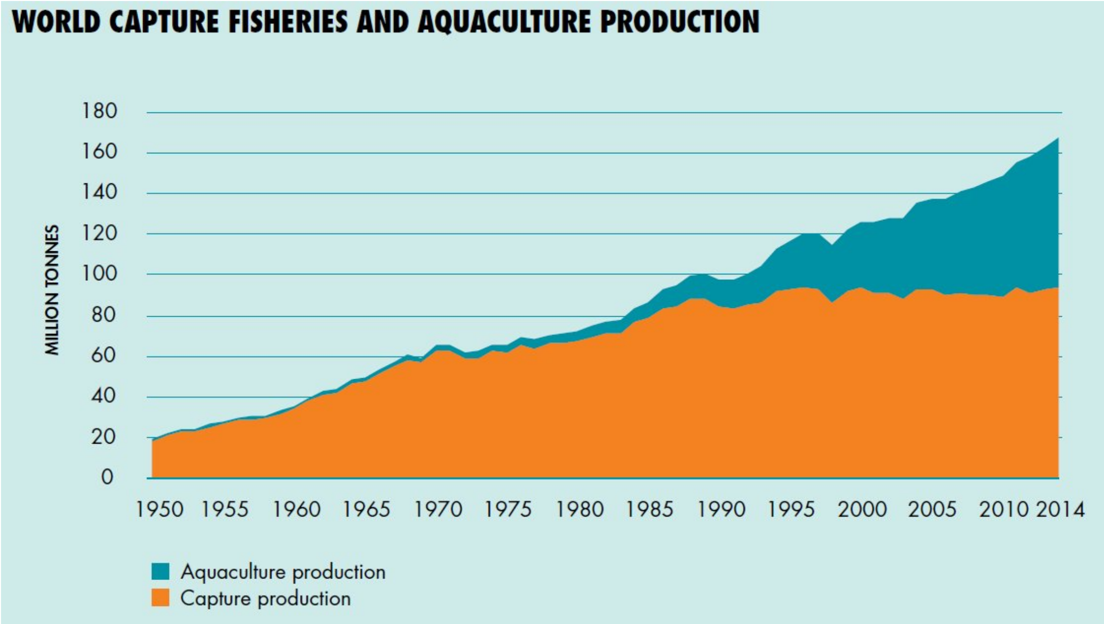


Figure 11. World capture fisheries and aquaculture production from 'The State of the Worlds Fisheries and Aquaculture' released 7th July 2016.

Much of this growth is attributed to the overcapitalisation of the global fishing fleet from subsidies (Pauly et al, 2002; Clark, 2006; Sumaila et al., 2010), defined as payments from public entities to the fishing sector, which increase profits (Sumaila et al., 2016). Total subsidies (mostly capacity-enhancing) are estimated to represent around USD $35 billion (Sumaila et al., 2016), and are a driving factor behind excessive fishing capacity, undermining the sustainability of marine resources and those that depend on them (Clark et al., 2006; Failler, 2007a Sumaila et al., 2010) Globally, fisheries provide revenue and jobs, with direct global landings valued overall between $80 and $85 billion annually (FAO, 2016), even though over half of the landed value is lost through mismanagement (Arnason 2011). The secondary economic impact has been suggested to be as much as $225–240 billion annually for fisheries (Dyck and Sumaila 2010). With 56.6 million people engaged with fisheries and 4.6 million fishing vessels (FAO, 2016), the industry supports around 560 million people (~8% of the world's population) and the number is growing (Eide et al, 2011). Fish consumption is steadily increasing in developing (now 18.8kg/yr), low-income (7.6kg/yr) and developed (26.8kg/yr) countries. With a further 2 billion people projected in Africa, Asia and Oceania by 2050, an extra 75 million tonnes of fish would be required annually (Rice and Garcia, 2011).

In 2013, fish provided 17% of the world's animal protein, including >20% for 3.1 billion people. The share of fish production eaten by people has risen from 67% to 87% over the last 50 years; the remainder is mostly used for feeding livestock or aquaculture (FAO, 2016).

Traditional coastal fishing grounds are declining in productivity (Jackson et al., 2001; Worm et al., 2006; Jackson 2008), but it has been difficult to recognise this due to humanity's collective 'baseline' perception changing with each generation (Pauly et al, 1995; Papworth, 2009). Daniel Pauly (1995) developed the concept in relation to fisheries management where scientists sometimes fail to identify the correct 'baseline' population size (e.g. how abundant a fish species was, or how extensive a habitat had been, *before* human exploitation and interference). Thus, science fails to correctly articulate the current 'shifted baseline'.

The expansion of global fisheries is associated with a declining in biomass of fishes (both target and by-catch) and subsequent ecological changes (habitat and assemblage) (Worm et al, 2006). Whilst declines in biomass are a consequence of fisheries over-exploitation, the concern for the fisheries sustainability lies in minimizing and managing the ecological changes that occur during this process (Worm et al, 2009; Salomon et al, 2011). These ecological changes can occur either as a result of direct effects, such as fishing gear that degrades the habitat, or indirect effects such as food web changes and biodiversity loss (that degrades the assemblage). The challenge is in reforming conventional fishing policies and practices to facilitate future sustainability (see for example Salomon et al., 2014 on reform of the European Unions Common Fisheries Policy)

It has been suggested that reducing a fishery's biomass to 25-50% of unexploited levels typically maximizes their yields, whilst going beyond this can result in biodiversity loss and other negative ecological processes (McClanahan et al, 2011). However, if the science of exploitation demands such high levels of exploitation

(50-75% of biomass!), it helps to contextualise how large an influence modern fisheries have on global stocks. In the seas adjacent to developed nations, many fisheries were reaching levels of maximum or overexploitation from the 1980s; in the waters of developing nations, this level of extraction was not reached until the 2000s (Worm and Branch, 2012). The State of the Worlds Fisheries and Aquaculture (FAO, 2016), reports that currently 31% of marine fisheries are overfished, 58% are fully-fished, and just 11% under-fished. In addition, presently only 69% of marine fisheries are now biologically sustainable, down from 90% in 1974 (Figure 11)

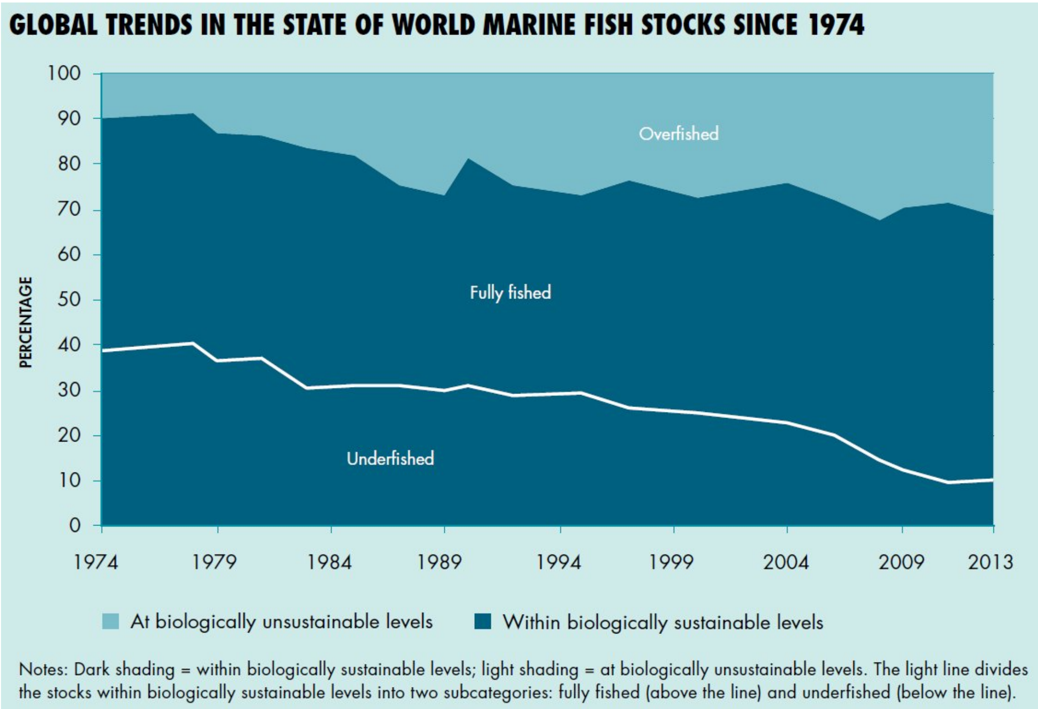


Figure 12. Global trends in the state of world marine fish stocks since 1974 from 'The State of the Worlds Fisheries and Aquaculture' released 7th July 2016.

Today fishing effort continues to rise despite a peak in yields in the 1990's (McClanahan et al, 2015) with an estimated 25-50% of global fish stocks reduced to a biomass of below 10% of unexploited levels, and can thus be considered 'collapsed' (Worm et al, 2006). Some places, such as the North-East Pacific, are doing relatively well (14% overfished), whilst others, such as the Mediterranean and Black Sea, are faring badly (59% overfished) (FAO, 2016).

The highest frequencies of collapsed stocks are in species-poor environments (Worm et al. 2006) and in areas such as the Mediterranean Sea this problem is most acute (Tsikliras, 2013b, EUROPA, 2016). In developed countries such as Greece, overexploitation of fisheries is at chronic levels (Tsikliras, 2013a). Here, a knock-on effect of the collapse of local stocks is an increased demand for fish from further afield, particularly tropical waters (Smith et al, 2010; FAO, 2016).

It is likely that much of the detrimental effect of fisheries' decline is being masked to consumers with increasing catches from developing countries in the Southern Hemisphere offsetting shortfalls in catch from developed countries in the Northern Hemisphere (Pauly et al, 2005; Smith et al, 2010). This is one reason why the selling of fishing access rights to foreign developed nations has often been portrayed in a negative light: allowing distant water fleets from developed nations to overfish traditional fishing grounds leaving little for regional artisanal fishing fleets (local, small scale, low-technology fishermen) and subsistence fishers to catch fish, generate income, or provide essential dietary sustenance (Atta-Mills et al, 2004).

If fisheries are going to be managed for food security (McClanahan et al., 2015), then the linked socio-ecological systems that sustain us should be examined at a global scale, and in a systematic and place-based manner, so that links can be drawn between the global and the local, and so that scale appropriate, and place appropriate management measures are proposed (Abesamis et al, 2006a, Béné et al., 2016). (Figure 12).

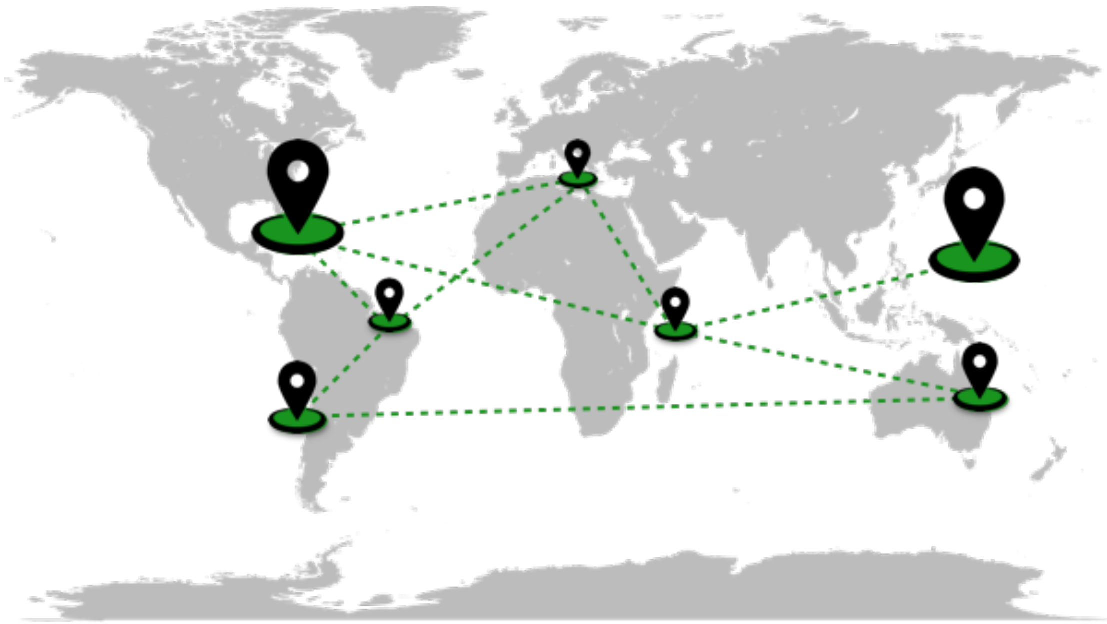


Figure 13. A map illustrating how a series of globally distributed, place-based case studies can inform understandings of global trends in fisheries management.

2.2 Acting Local

The goal of 'sustainable living' (in sustainable places) can be understood by studying the complex and dynamic interrelations between ecology, society and economy across various spatial scales. For global trends like overfishing, fundamental differences may occur locally between coupled socio-economic systems that are unique to place. By making connections across spatial scales, place-based research is tackling the vital issue of sustainability and sustainable places in a fundamentally new way, through transdisciplinary place-based problem solving.

When considered globally, fish and invertebrate extraction and consumption only comprise around 5% of dietary protein (FAO, 2008). However, this figure masks underlying disparities in the data. Estimates have suggested that around 2 billion people rely on fish for at least 20% of animal protein intake (FAO, 2008) yet in many poor, island and coastal fishing communities, produce from fisheries provides from around 50% (Bell et al, 2009) to 100% (Unsworth et al, 2010).

Such locally high dependence on natural resources can create conflicts between stakeholders, and the proposed application of environmental education to the management and use of coastal resources has faced challenges (Dijksterhuis, 1996). These challenges are particularly evident when trying to address what has long been seen as the diverging ambitions of conservation objectives, and aspirations for better living conditions (Randall, 1991), even though the two are not mutually exclusive.

Since the Millennium Summit of the United Nations in 2000, and the formation of the Millennium Development Goals (MDGs), and more recent Sustainable Development Goals (SDGs), food security and poverty reduction have been central to the world development agenda. Recent food security discourse stresses the need for multiple policy, economic and social actions that address consumer demand, access, supply and nutrition – "feeding the 9 billion" (Grafton et al, 2015; Béné et al, 2015). Addressing these challenges is seen as central to achieving world peace, since fish are such an important source of food.

However, catch is not expected to keep up with demand, threatening food security for the world's poorest (Pauly et al, 2005; Godfray et al, 2010a; Godfray et al, 2010b; Coulthard et al, 2011) and with it regional peace and stability. These are the areas where conflicts over both access rights and resource declines can trigger wider unrest and even 'fish wars' (Pomeroy et al. 2007). Such disputes over marine resources are more likely to lead to wider conflict and instability, especially in those regions where food insecurity is high, and communities are vulnerable, and in regions where local and state governance is weak or autocratic (McClanahan et al, 2015). This conflict can be heightened in those communities where fish and fishing play a crucial role in human meaning and culture (Jacques 2009).

International trade can contribute positively to local food security, by stimulating both export orientated and domestic production (especially in aquaculture) which creates local employment and economic growth (Jaunky, 2011), Locally and regionally, fish exports have been used to improve trade balances: for example, in Senegal in the 1980s and 1990s the value of exported fish approximately equalled the value of imported of food staples (FAO 2008). Here, fish exports could be seen as making positive contributions to both food security and economic growth, although such benefits are difficult to demonstrate (Béné et al, 2010). The most recent analysis available suggests that while the local extraction of fish contributes undeniably to local, regional and global nutrition and food security, the links between fisheries, aquaculture, economic growth and poverty alleviation are complex and still unclear (Béné et al, 2016). Place-based case study research is needed for local patterns to be connected with global trends (Abesamis et al, 2006b; Halpern et al, 2008a; Béné et al, 2016). Specifically, the impacts of fish extraction and trade on food security and poverty alleviation are ambiguous and confounded by a focus on international trade and a lack of consistent methods (McClanahan et al, 2015; Béné et al, 2016).

Capture fisheries are extractive industries, and whilst such industries can significantly transform environments, communities and economies in a positive manner, such transformations may lead to conflicts or disputes amongst stakeholders. These conflicts can arise when costs and benefits are inequitably experienced or when developments are not compatible with individual stakeholder's interests and values (Davis and Franks, 2011).

To address this issue, more localised place-based studies (e.g. Pilgrim et al, 2007; Abesamis et al, 2006b; Unsworth et al, 2014, Baker et al, 2015) are needed that allow for socio-ecological links to be identified between local ecosystem productivity (coastal habitats and their associated species assemblage), extractive industries (fisheries production) and local social system sustainability (fisheries consumption). Ideally, such studies would follow a consistent conceptual framework so that links can be made between the local and the global across spatial scales.

2.3 Context Focussed Fisheries Research

Global fisheries are overcapitalised and over-subsidised, (leading not only to losses in gross food production, but also to larger losses in potential income) but at a regional and local scale this varies considerably (World Bank 2009; Sumaila et al., 2016). There is increasing recognition in the developed world of the need to reduce fishing effort and better manage marine resources, but where and how to do this remains unclear (McClanahan et al, 2015). Worm et al. (2009) suggests that around 63% of the 'better studied' fish stocks need better management directed towards stock rebuilding, but this can create conflict with fishers, especially when collapsed stocks are not guaranteed to recover (Froese and Proelb, 2010; Hilborn et al, 2012), or where there is little personal incentive to comply with management initiatives.

The over extraction of marine resources (leading to stock collapse) has been extensively documented in fisheries and follows a familiar pathway across many different fish stocks. The pathway has eight stages (after Talbot, 1993 in Lindenmayer, 2005):

Stage 1 - A new fishery or a new method of harvesting an existing stock is discovered.

Stage 2 - The new resource is rapidly developed with little or no regulation.

Stage 3 - Major fishing effort results in over-capitalisation of the equipment used to harvest the resource.

Stage 4 - Fishing capacity outstrips the potential of the fishery to sustain harvesting levels.

Stage 5 - The fishery is depleted and the level of harvest begins to decline.

Stage 6 - Fishing effort is intensified to offset the decline in the harvest.

Stage 7 - Intensive fishing effort continues to service investments made on over-capitalised equipment.

Stage 8 - The fishery is depleted to levels below which it is uneconomic to harvest, or the fishery is fully collapsed.

In some cases, attempts to manage the fishery occur in Stages 6 and 7, such as putting in place quotas and economic subsidies or reducing the fishing capacity of the fleets (Lindenmayer, 2005). However, management efforts at Stages 6 and 7 are often belated and ineffective, particularly given uncertainty about the resource (Halpern et al., 2008a), the lack of information on the ecology of the target species and the fact that the industry with vested interests will lobby hard to protect those interests (Pauly and Watson, 2003; Lindenmayer, 2005). In addition, subsidies at these stages may mean that a given fishing industry becomes artificially profitable, and fishers remain in the industry and continue to over-invest to obtain a greater share of a dwindling resource (Harris, 1998; Sumalia et al., 2010).

Several recent global surveys (that include both socio-economic and ecological criteria) have attempted to identify key regional and local geographic areas of problematic change (see Abesamis et al, 2006a; McClanahan et al, 2009; McClanahan et al., 2015). Although these use different methodologies (and therefore identified somewhat different regions), the ambition to identify and prioritise fisheries management locally should be applauded. These reviews also highlight the need for place-based research, which identifies place-appropriate management recommendations at the local scale:

"A place-based approach to sustainability science entails a relentless focus on context. It takes the spatially patterned, heterogeneous, fluid, networked, and contextually moderated form of socio-environmental processes as central points of investigation, rather than as mere modifiers of more general mechanisms"

MacGillivray and Franklin, 2015.

This was also the conclusion in Béné et al's (2016) review on the contribution of 'Fisheries and Aquaculture to Food Security and Poverty Reduction':

"local-specific [place-based] *case studies could be given more credence at the international level.* […because these studies are] *better able to capture the complex and multi-dimensional nature of the pathway through which fisheries and aquaculture effectively contribute to poverty alleviation, economic growth and food*

and nutrition security…" (p.187)

The challenge Béné et al (2016) identified is common to all case study research; how to extrapolate comparisons between places (with all their unique social, economic and ecological drivers), whilst identifying the common challenges and themes that can be addressed across multiple spatial and temporal scales and that ultimate contribute to the management of global issues:

"The challenge however is to remain true to the socio-ecological nuances found in particular places (case study analysis), while simultaneously drawing upon comparative lessons from other places, and setting them all within the context of global drivers)." (p.187)

The creation of sustainable places is inherently linked to the creation of sustainable livelihoods, since socio-economic system sustainability is ultimately dependent upon ecological system sustainability. 'Place-based' Ecosystem Based Management (EBM) decisions require resource managers to make choices based upon a range of social, ecological and economic criteria. This is because across coastal seascapes there are suites of ecosystems (habitats and assemblages) that provide a range of services to society.

Such "ecosystem services" are generally categorised after the Millennium Ecosystem Assessment into four categories: supporting services (e.g. coastal defence and erosion control), provisioning services (e.g. provision of fisheries and raw materials), regulating services (e.g. water purification and nutrient cycling) and cultural services (e.g. recreational and spiritual benefits) (Barbier et al, 2011). The term "ecosystem services" was coined in 1981 by Ehrlich and Ehrlich as a metaphor to communicate the importance, and thus the 'value' of nature to human societies. Whilst the ecosystem services concept has received broad support in the biological sciences, the business and management supply chain literature has been slower on the uptake, with scholars often ignoring the availability of resources as a supply chain risk (Matopoulos et al., 2015). That said, progress has begun to be made in the field of 'Ecological Economics' since the publication of Robert Constanza et al.'s

(1997) landmark paper calculating the 'price of services' provided by the environment.

For over a decade, a variety of advisory panels (see Pikitch et al, 2004) have championed EMB thinking and recommended ecosystem based fisheries management (EBFM). Indeed, it has been hailed as:

"new direction for fishery management, essentially reversing the order of management priorities to start with the ecosystem rather than the target species"

Pikitch et al, 2004.

However, EBFM is not without its challenges, and current approaches lack information on the spatial distribution of marine species, making it essential to improve our understanding of fish-habitat associations to support sustainable EBFM (Moore et al., 2009).

Fisheries provision is the ecosystem service of particular concern to this study. Globally, place-based studies of coastal habitats have recorded different species of fish utilising different habitats either as juveniles or adults or both (Nagelkerken, 2000; Mumby 2006; Unsworth et al, 2008; Lilley and Unsworth, 2014). As such, the loss of a particular habitat type within the broader coastal seascape can have profound implications for local fisheries (Mumby et al., 2004; Bertelli and Unsworth, 2013).

For example, Mumby et al, 2004 found the Rainbow Parrotfish (*Scarus guacamaia*), are totally dependent on mangrove habitat and are not seen where mangroves are absent (Figure 14). This has implications locally for fisheries (Debrot 2008), but the results cannot necessarily be scaled across different species in different places.

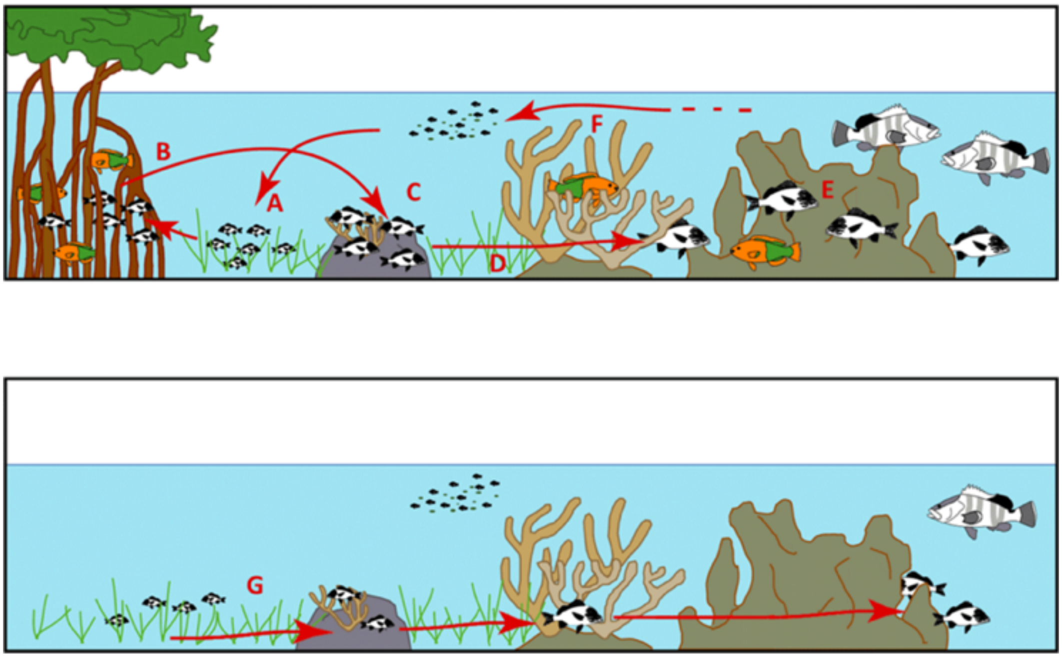


Figure 14. Modified from Mumby et al, 2004. The figures illustrate how connectivity between seagrass meadows, mangroves, and coral reefs can affect the size and density of fish (e.g., grunts and parrotfish). Top - Mangroves Present: Red letter "A" shows juvenile grunts, once reaching a given size in a seagrass meadow, moving to mangroves (B). The mangroves serve as an intermediate nursery habitat before the fish migrate to patch reefs (C), and fish biomass is significantly enhanced on patch reefs (C), shallow forereefs (D), and Montastrea reefs (E). Some fish (F), such as certain species of parrotfish, *Scarus guacamaia*, are dependent on mangroves and are not seen where mangroves are absent. Bottom - Mangroves Absent: If the mangroves are not present, then fish move directly from the seagrass meadows to the patch reefs, appearing on patch reefs (G) at a smaller size and at lower density, thus more vulnerable to predation.

Of concern for the sustainability of global fisheries is thus the decline in both size and health of coastal habitats over the last century (Jackson et al, 2001; Jackson et al, 2008). In tropical seascapes, there has been a considerable global decline in mangrove extent to the order of 1-2% year^{-1} (Valiela et al, 2001) and coral reefs by 1-7%year^{-1} (Bellwood et al, 2004), depending upon the interaction of local and global (e.g. El Niño) drivers that can lead to regime shifts (see Rocha et al, 2015 for review).

For more globally distributed habitats such as seagrass meadows, the figure is at least 1.5% of seagrass meadow extent lost per year^{-1} (Waycott et al, 2009) with almost 29% of the historic extent of seagrass having disappeared globally since 1879 - implying that just under 1/3 of the goods and services they provide has already been lost (Telesca at al., 2015).

Ecosystem goods and services degradation have posed a number or risks to business supply chains and there are several famous examples, not least the much publicised 'coral-to-algal' regime shifts in Caribbean coral reefs (Jackson et al., 2014). For example, Jamaican coral reefs underwent a major regime shift in the 1980s, with coral cover declining from 52% to 3% and macro-algal cover increasing from 4% to 92% (Hughes 1994). These changes were largely attributed to long-term overfishing (assemblage) and land-based pollutions which enhanced algal growth (habitat), resulting in an ecosystem that lacks the productive fisheries of before (Jackson et al., 2014).

A shift in focus to EBFM is being championed to put the ecological system at the heart of the decision-making process (Pikitch et al., 2004) to support the continued delivery of ecosystem goods and services (Barbier et al., 2011) by protecting *Nature's* capacity to supply them (Diaz et al., 2015)

2.4 Ecosystem Based Fisheries Management (EBFM)

The overall aim of Ecosystem Based Fisheries Management (EBFM) is to promote and sustain healthy marine ecosystems and the fisheries they support. In particular, EBFM should:

i. avoid degradation of ecosystems, as measured by indicators of environmental quality and system status;

ii. minimize the risk of irreversible change to natural assemblages of species and ecosystem processes;

iii. obtain and maintain long-term socio-economic benefits without compromising the ecosystem;

iv. generate knowledge of ecosystem processes sufficient to understand the likely consequences of human actions.

Where knowledge is insufficient, 'robust' and 'precautionary' fishery management measures that favour the protection of the ecosystem should be adopted. Essentially, the objective under EBFM is to ensure the sustainability of a given ecosystem so as to ensure the perpetuity of the ecosystem services they provide (Guerry, 2005).
The fact that much of the literature has not traditionally considered dependence on ecosystem service provision as a a risk factor (or indeed the ramifications to the supply chain of the loss of such ecosystem services), might well be because of a tendency to focus on the more traditional environmental management themes relating to pollution and environmental impacts, rather than any notion of environmental dependence (Matapoulos et al, 2015).

Progress is now being made and a suite of tools and methodologies are being developed that can help in the commercial assessment of ecosystem services; including software e.g. Ecometrica and ARIES, non-governmental initiatives e.g. Natural Value Initiative (naturalvalueinitiative.org) and the Natural Capital Project (naturalcapitalproject.org), or targeted publications e.g. The Corporate Ecosystem Services Review (World Resources Institute, 2008).

However, despite the relevance of natural resource based industries to the field of management and business research, and particularly to the field of Supply Chain Management (SCM), the interaction between a supply chain and natural resources is 'very often ignored' (Matapoulos et al, 2015).

Business and management research literature has identified a need for *'innovative multi-disciplinary methods for resource use and impact analyses that can handle the dynamics and complexity of current food systems'* and research should try and tackle issues such as *'the impact of resource scarcity on the nature of supply chain relationships'* (Matopoulos et al, 2015).

Adopting an ecosystem goods and services approach to sustainable SCM would provide a common platform for discussion with environmental scientists on how to address the impact of resource scarcity on 'goods and service' provision, whilst also facilitating a framework through which the dynamics of resource use can be articulated.

This issue has been previously highlighted by natural resource-based view (NRBV) scholars Hart and Dowell (2011) and in several SCM review papers (Burgess et al, 2006; Defee et al, 2010; Ashby et al, 2012). It has been noted that within the sustainable SCM literature very little reference is made to specific resources used, to the methods and tools applied to assess resource usage or to the overall supply chain configuration (Seuring and Müller, 2008; Miemczyk et al, 2012; Abbasi and Nilsson, 2012; Ashby et al, 2012; Abbasi and Nilsson, 2016). In fact, in a recent literature review, Matopoulos et al. (2015) claim that the *"majority of work"* conducted in this context ignores the availability of natural resources as a supply chain risk factor (see Bell et al, 2012).

However, the ecosystems service model is not without fault. One of the shortcomings of the Ecosystem goods and services model is in the culturally driven valuation of '*Nature's benefits to people*' and the vagaries of what exactly constitutes a '*Good quality of life*' (Costanza et al., 2008). Economic valuation essentially entails attributing importance to a certain good or service, and as such is always subjective (Spangenberg et al, 2015). In fact, saving biodiversity by internalising external cost has been described as an approach that is (in some cases) '*more than questionable*' but '*defendable if well done*' (Spangenberg et al, 2016). To address this issue this thesis will focus on a case study of one ecosystem service that is provided by nature to enable a good quality of life, namely fisheries provision and its role in food security. There are numerous definitions of food security, but an often-cited definition is that of the United Nations Food and Agricultural Organisation (FAO):

'when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'

FAO, 1996

Whilst there are again criticisms of this statement ('*food preferences for an active and healthy life*' (see Pinstrup-Andersen, 2009 for discussion), it is argued here that by narrowing the discussion from 'good quality' of life towards 'sufficient, safe and nutritious food' helps to focus the discussion on the sustainability of these supply chains.

Food security provision from aquatic habitats is largely provided by the fisheries they support; both directly through fishing in the habitat, and indirectly through supporting adjacent fisheries in other habitats (Nordlund et al, 2010; Unsworth et al, 2010; Lilley and Unsworth, 2014).

There has been much discussion about food security and the challenge of feeding 9 billion people (Godfray et al, 2010; Grafton et al, 2015) with a significant focus on marine fisheries (Pauly et al 2005; Béné et al, 2015; FAO 2016). In addition to this, consumer demands for increased traceability in supply chains is putting pressure on the fishing industry for increased transparency - providing seafood with a low environmental impact that is ethically sourced (Parkes et al., 2010).

2.5 Ecosystem Based Fisheries Management in Small-Scale Capture Fisheries

Small-Scale Capture Fisheries (SSCFs) are considered as a potential solution for working towards supply chain sustainability in the exploitation of fisheries resources (Matthew, 2003; Béné 2006; McClanahan et al., 2015; Béné et al., 2016). Of around 56.6 million active fishers (FAO, 2016), over 90% are small-scale operators (Béné 2016; FAO 2010) and the SSCF sector employs twenty-four times more fishers than the large-scale capture sector, for an equivalent annual catch for human consumption (Jacquet and Pauly, 2008). In addition, total annual fuel consumption is lower and food wastage from discards is smaller (Kelleher, 2005; Jacquet and Pauly, 2008). What characterizes small-scale fisheries is the diversity of their fishing techniques, methods and gear types as well as the fishers' intimate knowledge of local aquatic systems; and their 'Traditional and Local Ecological Knowledge' (hereafter TLEK).

Furthermore, a significant proportion of the catch is usually shared at the household or community level despite noted contributions to the local and global trade in fish products (Allison and Ellis, 2001; Chuepagdee 2011). This leads to the under-appreciation of the economic importance of small-scale fisheries in sustaining coastal communities, and a concerted effort is required to preserve the ability and "freedom" of small scale fishers to operate and to contribute to local, regional and global sustainability (McClanahan et al., 2009; Jentoft, 2011). In many places, the marginalization of small-scale fisheries is highlighted by inadequate financial, institutional and scientific support for small-scale fisheries combined with a political under-representation of the concerns of people working in the sector (Salas et al. 2007; Béné and Friend, 2011).

In December 2002, The Fourth Session of the FAO Advisory Committee on Fisheries Research (ACFR):

"highlighted that small-scale fisheries had not received the research attention that they deserved, considering the important contribution that they make to nutrition, food security, sustainable livelihoods and poverty alleviation, especially in developing countries."

The ACFR recommended that a working party be convened, and in 2003 the Director-General of the FAO convened the Working Party on Small-scale Fisheries.

"to undertake an evaluation of the role and importance of small-scale fisheries, elaborate a research agenda for the sector, review strategies and mechanisms to bridge the gap between research and action and provide views on key elements that should be included in the draft guidelines on small-scale fisheries."

Despite these developments, Jaquent and Pauly (2008) note that the social, cultural and economic importance of small scale fisheries has largely been marginalized, ignored or dismissed. Yet it is only through considering the Social, Economic and Ecological systems of small scale fisheries that we can promote sustainable place creation through sustainable resource use.

Following the inaugural World Small-Scale Fisheries Congress (WSFC), held in

Bangkok, Thailand in October 2010, the Global Partnership for Small-Scale Fisheries Research (SSCF), "Too Big to Ignore" (TBTI), was established as a forum for collaborative research, policy dialogue and advocacy on issues pertinent to SSCFs. TBTI focuses on elevating the profile of SSCFs, to argue against their marginalisation in national and international policies, and to develop research to address global food security and sustainability challenges in fisheries policy. Disaggregating industrial and SSCFs is key to achieving this aim, and in promoting the social well-being, socio-ecological resilience and cultural heritage that can be achieved through well managed small-scale fisheries (Béné et al., 2006; Srinivasan et al, 2010; Béné et al., 2015). Despite this progress, Béné et al (2016) note an:

"*urgent need for more studies in capture fisheries to explore the local level impacts of global drivers on food security*" because of "*the lack of reliable data on small-scale fisheries*".

Noted in the FAO (2004) 'Research Agenda for Small-Scale Fisheries' was the increasing globalisation of trade, and with it, market access-related phenomena such as food and safety concerns and environmental labelling. These developments create both opportunities and risks for SSCFs:

"and in some cases move decision-making beyond the immediate reach of small fishing communities or fish workers."

Staples et al. 2004.

To improve a SSCFs adaptive capacity requires data, and for SSCFs the information requirements must cover harvesting and catches, processing, marketing and the fishing community – or simply the supply chain from 'catch to market' (FAO, 2016). Research studies that address specific gaps and provide detailed information are needed to support management decisions (Kellerher et al, 2012). The data collected by the research should consider the *social* and *economic* circumstances of the fishers and their families, and define details of the *biology* and *ecology* of the resource base, marketing patterns or conservation needs (Kellerher et al, 2012).

The socio-ecological framework can offer useful conceptual grounding, and assist in developing proposals and management strategies which enhance the resilience of human-environment systems (Stokols et al., 2013). The socio-ecological lens points toward potential institutional remedies that are needed to reconnect the material, ethical and communitarian bases of otherwise autonomous systems. (Lejano and Stokols, 2013). As such, social-ecology is transdisciplinary, and seeks richer, often multiple ways to describe how changes in one dimension (e.g. ecological capital) are related to changes in another (e.g., financial capital). Central to this 'systems' concept is the current ecological state of fisheries in the region. On June 26th 2014 the European Commission announced that:

"96% or more of the Mediterranean bottom living fish are overfished, and for the middle-water stocks like sardine and anchovy the figure is 71% or more"

Europa (2014).

Of particular concern to this thesis is the estimated regression of Mediterranean seagrass meadows that has amounted to 34% in the last 50 years (Telesca et al, 2015) Such ecological degradation of regional fisheries will effect socio-economic outcomes for both fishing communities, consumers and the fishing industry (Pikitch et al., 2004), with the most recent study estimating that Mediterranean seagrass meadows could be worth around €190 million annually to commercial and recreational fishing. Knowledge of these socio-ecological links must surely challenge both fishing communities and industrial fisheries to adapt their behaviours in light of such stark ecological vulnerabilities?

In the same press release the European Commissioner for Maritime Affairs and Fisheries stated:

"I am very worried how badly things are going in the Mediterranean Sea… Now that scientists have assessed many more fish stocks over the last five years, the time of denial is over: the Mediterranean Sea is heavily overfished. I see a long struggle and hard work ahead: We need to build up the science, adopt regional fishing plans

to bring fishing down to sustainable levels. If we do not act now, we will lose the tremendous potential of these resources for future generations"

Europa 2014.

Therefore, to address this research gap, this thesis focuses on the implications for the future of SSCFs as extractive industries by developing the supply chain concept and moving beyond "catch to market" to incorporate the 'biology and ecology' of local resources into management thinking. The thesis provides an additional SSCF case study, addressing the urgent need for more studies in capture fisheries, and practically it provides much needed empirical data for SSCF researchers and managers working in the region.

However, beyond this, this thesis provides a novel conceptual framework for SSCM in SSCFs which promotes the integration of coupled socio-ecological systems thinking into conventional sustainable supply chain research. This novel framework achieves this synergy by focussing on Lipsi as a unique 'place' and thus providing a 'sense of place' to which stakeholders can identify.

A sense of place appears to most strongly motivate stewardship actions at local and regional scales under circumstances where people value a place for the same reasons, and the conditions of the place are deteriorating (Chapin and Knapp, 2015). In addition, it is also well-recognized that actions that build 'place attachment' can create a reservoir of potential stewardship, if locally valued places were to deteriorate (Chapin and Knapp, 2015).

Places are continually evolving (MacGillivray and Franklin, 2015), and therefore through conceptualising and analysing the Lipsi SSCF as being on a particular trajectory, this thesis alludes to intervention points that can re-orient the place of Lipsi towards a more sustainable pathway – a step towards sustainable place creation.

CHAPTER 3 – Place

3.1 The Hellenic Republic of Greece

The Hellenic Republic of Greece (Figure 15), covers an area of 131,957 km², and has a history and cultural heritage that resonates through modern Europe in its literature, art, philosophy and politics.

Figure 15. A map of Europe highlighting the location of Greece [inset - Map of the World].

However more recently, a global financial crisis has hit Greece particularly hard. In April 2010, following the Greek government's inability to refinance public debt from private creditors, the country entered a strict austerity regime coupled with extensive market reforms (Samitas and Polyzos, 2016). The severe economic crisis that has been affecting Greece since 2009 is having an unprecedented impact in terms of job and income losses and is widely perceived to have a comparably significant effect in terms of greater inequality and increased poverty (Matsaganis and Leventi, 2014).

In the marine environment, primary industries are significant. Greece’s extensive coastline (13, 676km) and numerous islands (>6000) have historically supported extensive fishing activity. At the beginning of this study (2012), Greece was ranked first for the number of fishing vessels in the Mediterranean amongst EU members, accounting for roughly 1/5 of the EU's Mediterranean fishing haul, with about 90% of this total haul caught in the Aegean Sea (FAO, 2014).

Unfortunately, overfishing and poor fisheries management has reduced the relative economic contribution of fishing and has threatened regional food security (Tsikliras et al., 2015). Despite a high level of fish exports Greece still imports more fish than it exports, including fish meal for aquaculture, cephalopods, and marine finfish for the domestic market (Eurofish, 2014).

3.2 The Greek Seafood Sector

In Greece, there is one National Licence for commercial coastal fishing, Licence (Art.1 of Royal Decree No. 666 of 1966) and one from the European Union, Licence (Art. 1 of Council Regulation No. 3690/93 of 1993). These are further divided into licence’s for (i) offshore fishing (large-scale), and (ii) coastal vessels (small-scale). Whilst large-scale fishing occurs throughout the northern Dodecanese waters (the vessels are based on the islands of Kalymnos, Leros, Patmos) the fishing fleet of Lipsi is entirely small-scale and operates entirely in Lipsi’s coastal waters (Chapter 7).

Both of these fishing activities interact and can at times directly compete for the same marine resources (Pauly, 2006). Industrial fishing has increased to the detriment of small-scale artisanal fisheries in the Mediterranean (Gómez et al., 2006). Yet, it is small-scale fisheries (with few discards, and gears that cause little damage to habitats) that are more sustainable in the context of marine resource overexploitation (Tudela, 2004; Jacquet and Pauly, 2008). Thus, maintaining small-scale fishing activities is now increasingly recognised as a priority (Allison et al, 2001; Béné et al, 2016).

Broadly speaking, the Greek seafood industry can be divided into three major sub-industries:

A. Marine Capture Fishery
B. Aquaculture
C. Processing and Marketing of Products

A. Marine Capture Fishery

According to Greek administrative classification criteria the (A) Marine Capture Fishery has three main sub-categories:

a) "High-seas fisheries": operated by large trawlers on the high seas including vessels that are involved with the transportation of fishery products from the fishing area and quantities caught are reported as 'frozen'. This has also been referred to as "overseas/distant water" fishery by Moutopoulos et al, (2015) and includes very large vessels fishing outside of the Greek Exclusive Economic Zone equivalent waters i.e. in the Atlantic and along North African Mediterranean coasts. (NB not present in the study area, see Chapter 7 but does have implications on the socio-economic system, see Chapter 8).

b) "Industrial / large-scale fisheries": predominantly characterised by trawlers, purse-seines and mixed vessels (i.e. those licensed to operate as both a trawler and purse-seiner up to 2005 after which time vessels had to be licensed for specific gears (Moutopoulos et al, 2015). Operate in the study area.

c) "Coastal / small-scale fisheries": characterised by small boats (<15m) usually employing (95%) static / set gear: gill nets, trammel nets, hooklines, longlines and traps (Moutopoulos et al, 2015). Although some active / towed gear is used elsewhere in Greek waters, these gears are not present in the study area (see Chapter 7). The use of beach-seines was banned from 2013 (European Regulation, ER 1967/2006).

In addition to the three officially recognised sub-categories, there exists an additional sub-category:

d) “Sport / recreational fisheries”: of note because of this category’s competition with (a) the small-scale coastal fisheries (Cadiou et al, 2009).

This thesis is primarily concerned with the Marine Capture Fishery and in particular the Small-Scale Capture Fishery (SSCF) sector. However, to interrogate this sector fully, an understanding of both (B) Aquaculture and (C) Processing and Marketing of Products is important, especially in contextualising ‘place’ and in understanding the socio-ecological system in which the fishery operates (Chapter 8).

Presented here is information relating to the fisheries of the Dodecanese: namely (1) Offshore/ large-scale, (2) Coastal/Small-scale and (3) Recreational/Sport fishing.

Offshore / Large-Scale Fisheries

Offshore licences include one for trawling, and another for combining trawling and purse seining. Vessels in the second category are usually those manufactured earlier, and they retain a competitive advantage by being able to alternate across fishing seasons. Offshore fishing is limited seasonally depending upon gear type (Table 4); there is a closed season for Greek trawlers from the 1st of June to the 30th of September, and for purse seiners from the 15th of December until the end of February (Kapantagakis, 2007).

Table 3. Calendar highlighting the closed season for both Trawl and Purse-seine fisheries.

	WINTER			**SPRING**			**SUMMER**			**AUTUMN**		
MONTH	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Trawling												
Purse-seine												

Under the European Unions (EUs) Common Fisheries Policy (CFP), the bottom-trawl fishery is designed to exploit sandy or muddy bottoms at depths greater than 50m. For this reason, the shallow seagrass (*Posidonia oceanica*) habitats are 'in principle' unaffected. Trawling over sensitive habitats such as seagrass meadows and maerl beds is forbidden through European Comminsion (EC) and national regulations. (STCEF, 2013).

The specific management measures imposed by the EU legislation through the CFP include:

a. prohibition of fishing in depths less than 50m or at a distance less than 3 miles from the coast (whatever it comes first)

b. prohibition of fishing at a distance less than 1.5 mile from the coast (independently of depth)

c. various monitoring, control and surveillance, regulations and linked to gear specifications.

Linked to the CFP legislation, there exists (pre-exisiting) Greek national legislation dictating that the bottom trawl fishery is closed from June to September (4 months) and is not allowed at a distance less than one mile from the coast. The latter measure has been outweighed by the 1.5-mile trawl ban established through the EC legislation. (STCEF, 2013)

The number of the vessels (as in all other fleet segments) is constantly reducing due to the decommissioning plans enforced by the Ministry of Agricultural Development and Food since 2003 and after the enforcement of E.C. Regulations. However, because many vessels are burdened with debt (a situation made worse since the economic crisis due to the high interest rates of banks) the fleet has a *"tendency not to replace old vessels"* (EU 548016, 2013).

Coastal / Small-Scale Fisheries

Coastal fishing vessels are restricted to the SSCF fleet and are the focal sector of this thesis (Figure 33). In contrast to the offshore fleet, these vessels utilise numerous different gears, defined in terms of fishing gear, target species and season. This activity exploits coastal shelves at water depths less than 100 meters with small boats and little investment (Tzanatos et al, 2005; Stelzenmüller et al., 2007; Jacquet and Pauly, 2008).

Figure 16. A small-scale fishing vessel deploying static fishing gear (Photo:1- 4-2014, Leros)

Specific gears can be active throughout the year whereas others show a seasonal pattern of activity. (Tzanatos et al, 2006b). Fishing strategy including factors affecting gear choice and switching among the different gears is complex and varies both spatially and temporally.

The small-scale fishery utilises a multi-gear (multiple gear) approach including gillnets, trammel nets, longlines, and handlines. Most fisheries in Greece are multi-species in nature, and thus the definition of 'target species' in such fisheries is usually not straightforward (Tsagarkis et al, 2014). In small-scale fisheries, social, economic and ecological processes all drive gear choice and fishing strategy. These coastal fisheries continue to be both socially and economically important, employing many fishers who do not have alternative livelihood options in isolated areas.

Sport / Recreational Fisheries

In addition to commercial fisheries there is growing evidence of considerable extraction rates from recreational fishing activities. Fishing is one of the most frequent recreational activities in coastal zones (Morales-Nin et al., 2005) but it has been rarely studied (Lloret et al., 2008). Evaluating and managing this activity is challenging because it is so poorly organised and surveyed (Rocklin et al, 2011). However, acknowledging the impact of recreational fishing activity has become critical because of the unprecedented level of extraction overall.

There is now greater emphasis on studying the impact of recreational fishing on marine resources and ecosystems (Coleman et al., 2004), including the use of innovative sampling techniques different to those used for commercial fisheries (Pitcher and Hollingworth, 2002). The decline of commercial small-scale fisheries (Gómez et al, 2006) and the estimation that recreational activity represents 10% of total European fishery production (EU 2004; Font and Lloret, 2014) means that recreational fisheires are now an important area for research consideration. Especially since any increase in recreational activity may weaken the sustainability of the commercial Small-Scale Capture Fishery sector.

Recreational fishing on Lipsi spans several categories, from the dozen or so licensed fishermen who use any of the aforementioned methods, but only on a part-time basis, to those who angle from the shore. Recreational fishing is defined within this thesis as fishing for personal consumption. The various recreational fishing activities pursued on Lipsi include (Figure 43):

(a) Angling,
(b) Spearfishing and
(c) Non-commercial Small-Scale Capture Fishery

It is important to consider that each of these is implicated in a variety of biological and ecological impacts (Lloret and Font, 2013). It has been estimated that non-commercial SSCF has the largest extractive potential, followed by spearfishing and angling (Font and Lloret, 2014).

Figure 17. The recreational fishing sector on Lipsi includes (a) angling, (b) spearfishing and (c) non-commercial small-scale fishing activities

B. Aquaculture

Marine finfish aquaculture represents 80% of the volume and 92% of the total aquaculture value; however, shellfish and freshwater production are important as they support rural employment (STECF, 2013). Shellfish and freshwater farms are mostly small and family owned whereas finfish farms are predominantly large (Figure 47). Greek aquaculture accounts for 11% of the total EU production in volume and 15% of EU production in value. The major producing countries are Greece (43% of the total volume), Turkey (29%), Spain (16%) and Italy (6%), (Anastasiou et al, 2014). The aquaculture in Greece is predominantly an export industry, with over 80% of production exported, with major markets including Italy and Spain. Fish is the second largest primary export after olive oil (STECF, 2013).

Figure 18. Finfish aquaculture farms are found on Kalymnos (pictured), Leros and Agathonissi. Lipsi has previously had an aquaculture facility but the operation has since finished (Photo © RJLilley, 21-06-2014 Kalymnos).

Greek aquaculture tends towards the large scale with most farms producing over 300 tons per year (one million euros) per year. The production of Mediterranean marine fish species during 2013 was 283.755 tons and was mainly based on farmed sea bass (*Dicentrachus labrax)* (42%) and gilthead sea bream *(Sparus aurata)* (54%). The extensive farming of these species has allowed their price to drop significantly (Stathopoulos 2002)

The rapid growth of the aquaculture sector continued right up until the onset of the global economic crisis of 2008 which created rapid social and economic changes (Anastasiou et al, 2014). Since then, aquaculture facilities have had to adapt to the new adverse socio-economic conditions through a range of human resource management changes (e.g. Naudé et al, 2012).

C. Processing and Marketing of Products

In the early days, as the export market developed, most fish were exported unprocessed and sold in Italy or other European Markets. Today's marketing channels are global, and the production includes whole fresh fish, gutted fresh fish and filleted fresh or frozen fish and the % of exported farmed fish is above 60% (Anastasiou et al, 2014). As the aquaculture industry, has grown, there has been increased vertical integration, with major fish farm companies now controlling their own packaging and processing facilities (Anastasiou et al, 2014). This allows some companies to control their supply to market through a combination of a year around production cycle and a range of processed products.

Frozen seafood consumption in Greece has also increased, reaching approximately 20% of the total seafood consumption in 1998, (Arvanitoyannis et al, 2004). Most frozen seafood is imported (Figure 48), approximately 90% in 2000 and 70% in 1998 (Stathopoulos, 2002 in Arvanitoyannis et al, 2004).

Figure 19. A selection of frozen imports in a supermarket in Agia Marina, Leros (Photo 19-07-2014, Leros).

The growth of frozen products in Greece for the period 2005-2030 is set to continue with the sales of frozen fish and other seafood products in supermarkets rising Failler, 2007b). Greek supermarket chains are becoming an important player in the seafood market and are therefore becoming key stakeholders in seafood provision.

3.3 The Climate and Weather of the Aegean Sea

The Aegean Sea constitutes the north-easterly part of the eastern Mediterranean Sea; it is flanked to the east by the Turkish coastline, to the north and west by the Greek mainland and to the south by the island of Crete. According to Poulos et al, (1997) the area is characterized by a *'typical Mediterranean type of climate'* (Table 3).

Table 4. The Climatic Characteristics of the Aegean Sea. Note: Place-based variability around these figures can be expected. For example, the dry period according the ombrothermic diagram by Bagnouls & Gaussen (1957) lasts almost seven months, from mid-March until early October. (Zervou et al, 2009).

Climatic Characteristic		Reference
Climatic Periods	Nov–Mar (Cool and Rainy) May – Sep (Hot and Dry)	Zakabas, 1981
Mean Annual Air Temperature	16°C - 19.5°C (Summer 24-26.5°C)	Poulos et al, 1997
Air Temperature Range	-25°C in the Winter +45°C in the Summer	Zabakas, 1981
Mean Annual Precipitation	400-700mm per year	Poulos et al, 1997
Mean Annual Relative Humidity	65-75%	Poulos et al, 1997

The typical 'Mediterranean Climate' is characterised by the predictable weather patterns that contribute to the warm, dry, and sunny weather so important to the Greek tourist industry over the summer months. A time analysis revealed the presence of a strong seasonal signal characterized by two main seasonal extremes, winter and summer (Ziv et al., 2004; Abudaya, 2013) with the transition between the winter and the summer occuring very rapidly in May and October (Abudaya, 2013).

In Greek Small-Scale Capture Fishery's (SSCFs), such distinct weather patterns are known to influence fishing activity (Tzanatos et al., 2005; Tzanatos et al., 2006). The climatic characteristic of particular concern to this study is that of the Etesians (northern sector winds) known locally as "Meltemi" (Figure 17), which blow over the Aegean Sea in summer and markedly affect human activities across the region (May, 1982: Kotroni et al, 2001; Ziv et al, 2004).

Etesian winds are highly persistent during the summer and dominate weather patterns across the eastern Mediterranean (Ziv et al, 2004). However, the Aegean Sea occasionally experiences southerly winds that sweep off the African landmass and are known locally as "Sirocco". During the warm period (May-September), the Etesian winds are associated with clear skies which persist for extended periods. The winds can often reach gale force in strength (Poulos et al, 1997), limiting Small-Scale Capture Fishery activity.

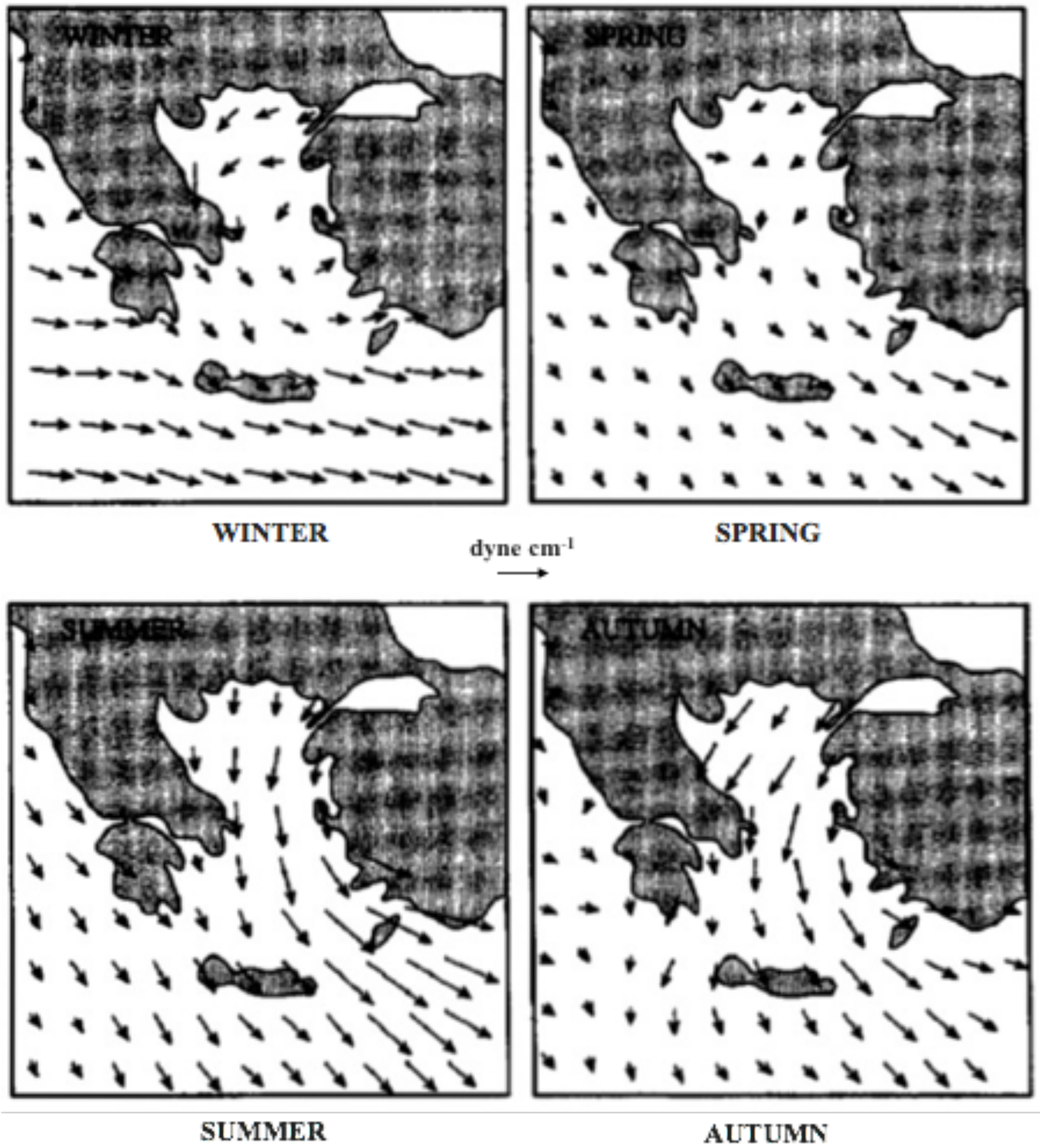


Figure 20. Seasonal variation in wind stress over the Aegean Sea (May, 1982)

3.4 The Socio-Economic Place: The Dodecanese Prefecture

The Dodecanese prefecture constitutes the eastern islands of the Notio-Aigaio one of thirteen administrative regions (the Cyclades prefecture constitutes the western islands). The Dodecanese (~162) cover an area of 2,714 km² but just 26 islands are inhabited. The 'northern Dodecanese' islands are those islands to the north of (but not including) Kos in the Dodecanese Island prefecture. The islands (Figure 18) represent the research area for the combined socio-ecological study detailed here.

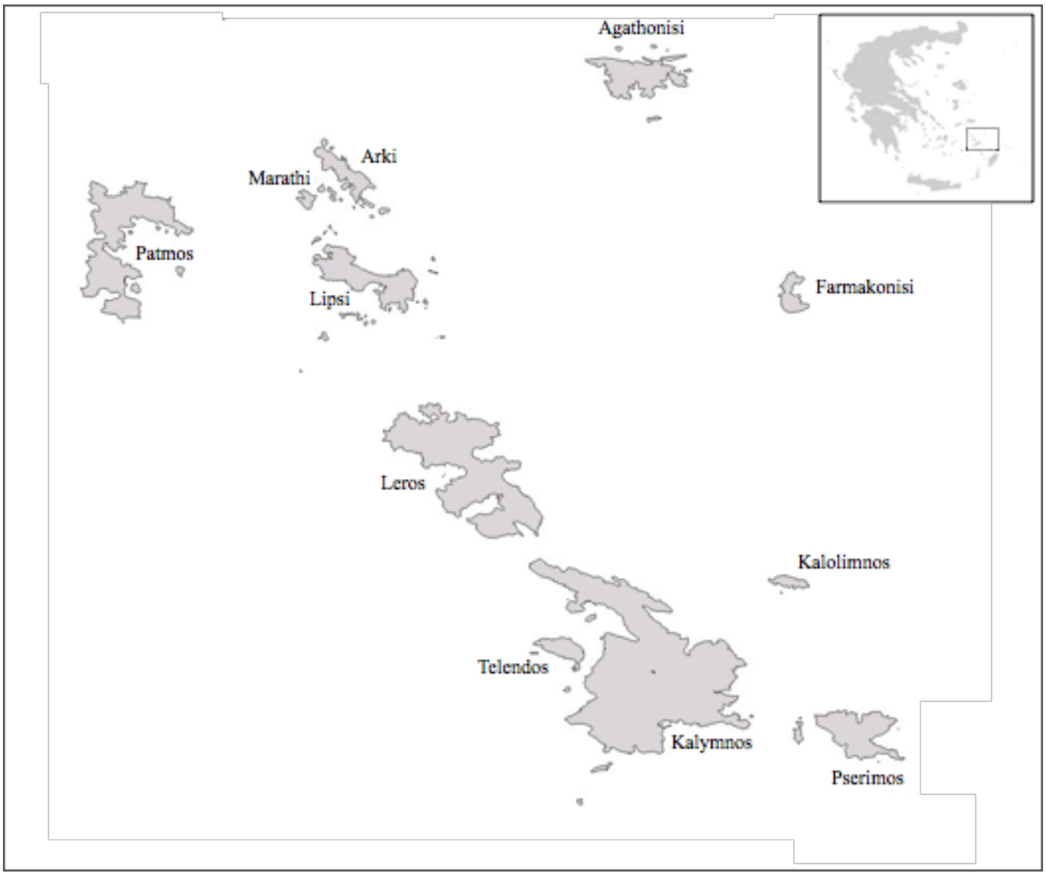


Figure 21. A map of the northern Dodecanese, [inset - Map of Greece].

In the summers of 2014 and 2015 socio-economic research (Chapters 8 and 9) was conducted on nine of these islands: Agathonisi, Arki, Marathi, Lipsi, Patmos, Leros, Telendos, Kalymnos and Pserimos. The two most easterly islands of Farmakonisi and Kalolimnos were not surveyed because they hold no permanent civilian population and instead support permanent Greek Army garrisons. The ecological survey (habitat, assemblage and fishery survey's (Chapters 5, 6 and 7) were conducted exclusively in the waters around the island of Lipsi across all four seasons.

The geography of Dodecanese is diverse, with much of the terrain infertile and rocky. Despite this, agriculture and fishing have traditionally been the chief occupations of the Dodecanese, with major crops being vines, olives, oranges, figs and tomatoes.

The fishing grounds exploited by the fishing fleet are not uniformly located along the coastal zone, with the major fishing grounds located in the most productive waters specifically "*the area between the islands of Patmos and Kos in the SE Aegean sea* [i.e the study area – Figure 18]" (FAO, 2008). These grounds are characterised by areas of shelf, with largely smooth and flat substrate suitable for bottom trawl fishing. Purse seiners (who set a large circular wall of net around fish, then 'pursing' the bottom together to capture them) target the edges of such areas, where uplift currents stimulate plankton and thus pelagic fish numbers. In contrast the SSCF fleet confines their activity exclusively to the coastal zone, (<3 nautical miles from the coast) targeting, islets, natural reefs and peninsulas.

3.5 The Ecological Place: The Municipality of Lipsi

Arki, Marathi and Lipsi are a contiguous set of three islet groups situated in the northern part of the Dodecanese prefecture. They consist of 37 islets, of which 3 (Lipsi, Arki and Marathi) are permanently inhabited: Lipsi = ~780-800 persons, Arki = ~40-50 persons and Marathi = ~ 8-10 persons. Each of the islets generally consists of a low altitude land formation, with the highest point reaching 277m (*Skafi*) on Lipsi itself. The hill slopes as well as the coasts are more or less of gentle gradient with other vertical rocky systems, valleys or specialized habitats not present (Panitsa and Tzanoudakis, 2001). The sea depth between the islets, and between them and Turkey, does not exceed 100m (Dermitzakis, 1990) with deeper waters situated to the west of the island.

The three main (and intertwined) occupations characterising the Socio-Economic System on the island are tourism, farming and fishing. In 2001 tourism was reported as a comparatively recent development on Lipsi, bringing with it the construction of roads, houses and hotels on the hills (Panitsa and Tzanoudakis, 2001). The growth in tourist activity has continued in the last 15 years with many new buildings recently constructed or under construction (Pers. Obvs.). The Lipsi Small-Scale Capture Fishery (SSCF) is the case study for this thesis, although the very small SSCFs of Arki (2-3 vessels) and Marathi (1-2 vessels) share the same fishing grounds. The

Port of Lipsi (urban area) is situated at Longitude: 26° 45′ 57″ E Latitude: 37° 17′ 39″ N (Figure 21).

Figure 22. A map of Lipsi, the urban area (dark grey) and its surrounding islets. The island can be roughly divided into the agricultural 'east' and the rocky 'west'. [inset] A map showing Lipsi situated within the northern Dodecanese archipelago.

The SSCF fleet of Lipsi (and across the northern Dodecanese study area) utilise a range of gears depending upon weather, season and market influenced supply/demand. Gill netting and Trammel netting are used to target demersal and benthic species, primarily in relatively shallow (<50m) habitats. Benthic longlines and Trammel nets are used to target demersal and benthic species at depth (>50m). Pelagic longlines are used to target swordfish (*Xiphias gladius*) and other large surface dwelling species. Handlining is used predominantly to target squid by "jigging" and some predatory fish by "trolling". Whilst each fisher will not have access to each technique, the small-scale fishery overall utilizes one or several of these to supply the community throughout the year.

Commercial fishing around Lipsi is a traditional activity and can be wholly described as both 'coastal' and small-scale. The fishery is characterized by both small boats (5.7m to 12.8m) and a limited number of fishermen (1 to 2 per boat). Fishing is coastal, takes place to depths less than 100 meters and within 90 minutes of the home port. Fishing activity changes seasonally and with target species, but is a daily activity, and fishermen catch mainly to supply the local demand, most of them selling their catch directly to local restaurants. The harbour (Figure 26) is particularly important in the summer months for both landing fish close to market (highest concentration of people), and when the Meltemi wind restricts fishing around the northern coast of the island.

Figure 23. The small-scale fishing fleet on Lipsi is governed by the Lipsi Fishermen's Association, and is made up entirely of boats <12m in length (Photo © RJLilley, 17-07-2014, Lipsi).

Both the 'Ecological System' (Chapter 5: Habitat and Chapter 6: Assemblage) and the 'Socio-Economic System' (Chapter 8: Market and Chapter 9: Consumer) of Lipsi are explored in this thesis. However, it is the Small-Scale Capture Fishery (SSCF) that represents the 'capture fishing industry' at the confluence of the two systems (Chapter 7: Fishery). Each of the five chapters / supply chain stages is relevant to the Sustainable Supply Chain Management of the seafood supply chain, and therefore to the sustainability of the Municipality of Lipsi as a 'place'.

3.6 Study Sites

Nine sites are utilised as throughout the study. These are presented in Figure 28, with information pertaining to each site's characteristics.

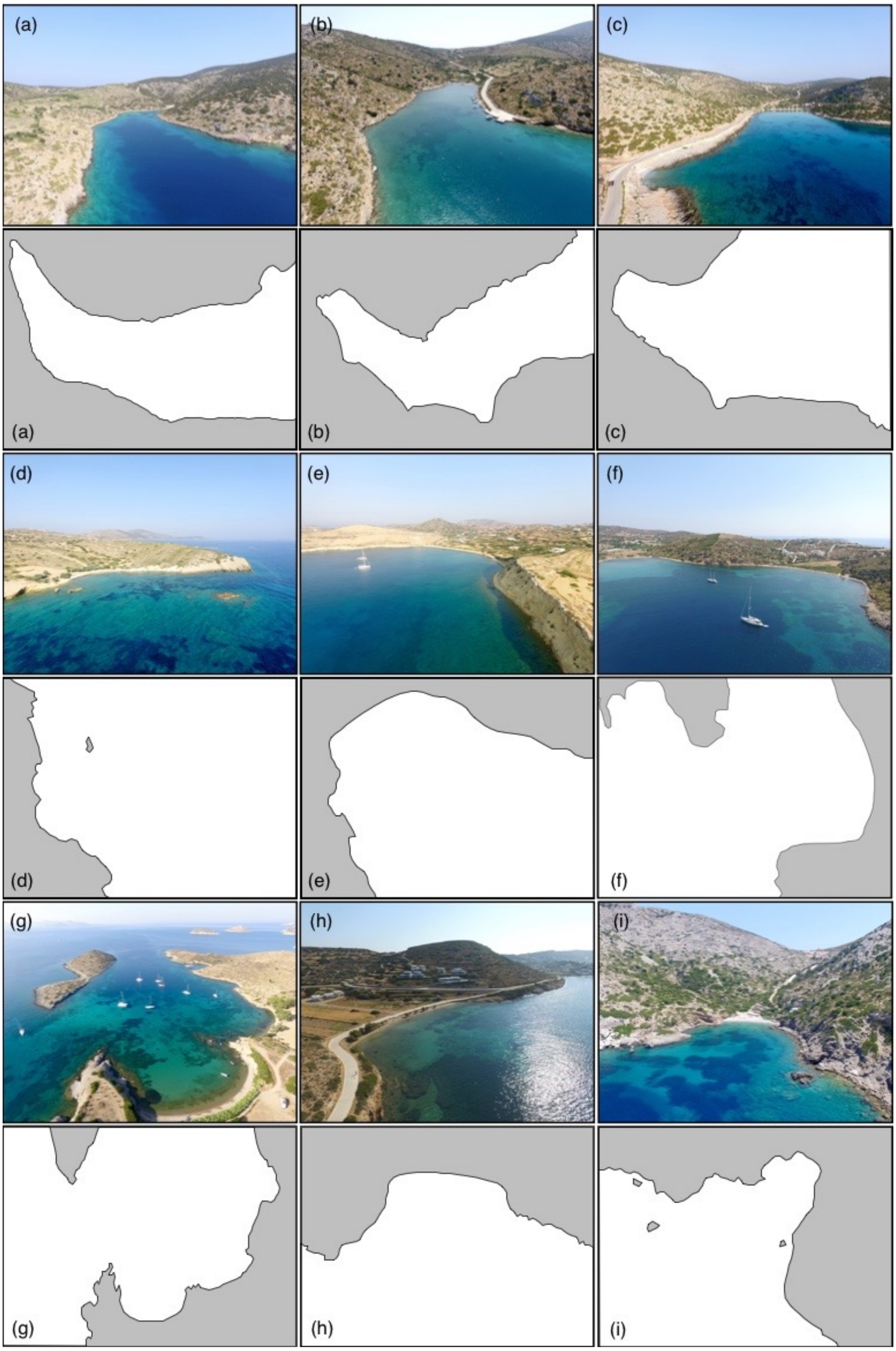


Figure 24. Each of the nine sites as identified by 1) UAV photography and 2) 2D mapping.

Vroulia (a): located in the far north-west with a municipal building at its entrance. It is only accessible by footpath. The bay suffers from sedimentation of the water column, especially after heavy rains, which originates from construction residue and the associated clearance of coastal vegetation.

Moschato (b): a small fishing dock also in the far north-west, it was the location of an Aquaculture facility for over 10 years during the 1990s and early 2000s. It is lightly used by fishers throughout the year but receives negligible commercial or recreational boat traffic.

Platis Gialos (c): a very popular and predominantly sandy bay. It experiences high recreational and commercial boat traffic due to its aesthetic appearance and popular Taverna. It is heavily marketed as a boat trip destination on neighbouring islands and is Lipsi's best-known tourist beach.

Kamares (d): a predominantly rocky habitat on the exposed north-east. It is difficult to get to on foot and by boat, and receives few tourists.

Chochlakoura (e): another sandy bay, popular with tourists. Being on the sheltered south-east it is often a haven for recreational boats.

Limnh (f): a sheltered bay with a dense seagrass meadow. Due to its proximity to neighboring Papadria, it currently receives little boat traffic.

Papadria (g): adjacent to the popular Taverna at Katsadia (accessible from Papadria). Both bays show signs of extensive boat anchor scarring within their seagrass meadows from the intensive summer boat traffic.

Kambos (h): located close to the main port of Lipsi and characterized by an intact seagrass meadow bordered by sandy habitat. It receives light boat traffic.

Kimissi (i): an isolated bay on the south-west dominated by dense seagrass meadows. It is accessible by road and is widely fished, especially during summer when fishers shelter from the north-westerly "Meltemi" wind.

3.7 Coastal Habitats

The coastal waters surrounding Lipsi island are characterized by a mixture of rocky and sediment bottomed areas. The seascape constitutes a variety of ecosystems, broadly defined as:

1) Seagrass meadows (*Posidonia oceanica),*
2) Rocky-algal formations,
3) Un-vegetated sandy bottoms and**,**
4) Coralligène reefs.

Posidonia.oceanica is restricted to waters shallower than 40m (Telesca et al, 2015), with Coralline Algae present in waters deeper than 40m (Georgiadis et al, 2009). Mean surface water temperatures range between 16-19 °C in winter (December, January, February) 20-24°C through the spring (March, April May), between 25-28°C in the summer (June, July, August) before cooling again through 20-24°C in the autumn (September, October, November). Surface salinity is constant throughout the year (39.5ppm ± 0.2).

Posidonia oceanica is a seagrass species endemic to the Mediterranean Sea, growing between depths of 0.5m to 45m (Procaccini et al, 2003) and covering an area of 1,224,707 ha (Telesca et al, 2015), equating to approximately 1-2% of the 0-50m depth zone (Pasqualini et al, 1998).

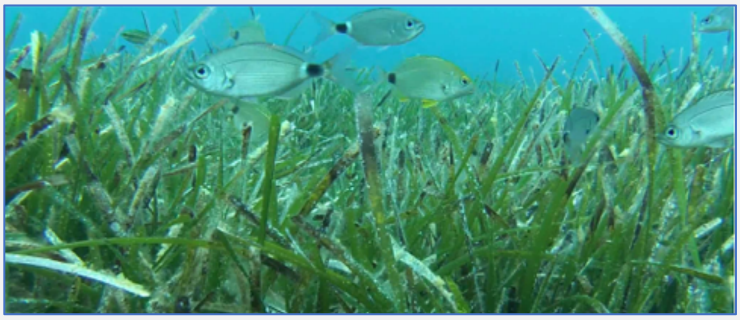
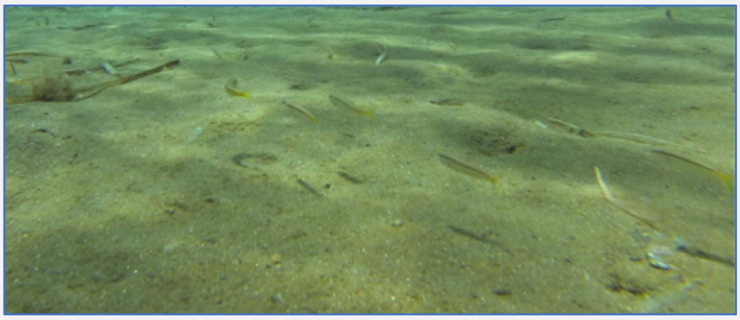
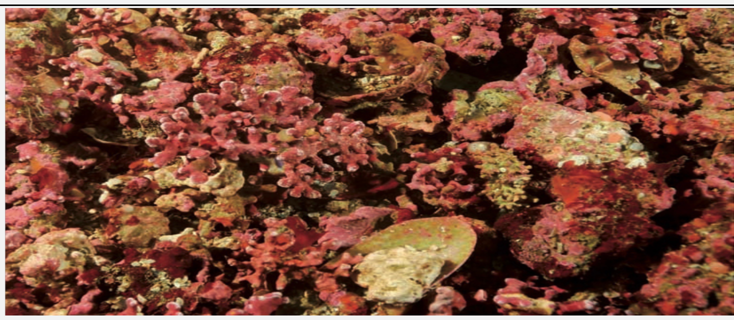
In Greece the projected figure is 44,939ha but no total historical area is available and only a fraction (8%) of these meadows have been mapped (Telesca et al, 2015). *Posidonia oceanica* meadows represent the dominant biological habitat type around Lipsi Island within the 40m depth contour (Figure 27).

Figure 25. Occurrence and distribution of seagrass meadows (*Posidonia oceanica*) around Lipsi Island showing the characteristic patterns associated with depth contours.

Visual inspection of habitat distribution around the islands reveals consistent patterns. In very shallow waters (0-3m range) *Posidonia oceanica* occurred in patches on both rocky-algal or sandy substratum. Very little *Posidonia oceanica* was found in waters less than 1m in depth and only in areas with minimal wave energy on the sheltered south-east side (Pers. Obs). From 3m-9m the patches of seagrass are generally replaced by more reticulate meadows of *Posidonia oceanica* interspersed with patches of bare sand. Between 10m-30m seagrass meadows are continuous before they become more reticulate and then patchy in deeper waters >30m (Pers. Obs., Borg et al., 2009). These findings are consistent with other studies of Mediterranean coastal seascapes e.g. Infantes et al, (2009) and Borg et al (2009).

It is widely accepted that light availability sets the lower limit of seagrass bathymetric distribution, while the upper limit depends on the level of disturbance by currents and waves (Infantes et al, 2009). A place-based understanding of these perceived patterns of habitat distribution throughout the study area is an essential starting point to evidencing fisheries contributions by particular habitat types (Moore et al., 2009) and to understand the impact of fisheries on habitat integrity (Puig et al., 2012).As aforementioned, it is essential to improve our understanding of fish-habitat associations to support sustainable ecosystem-based fisheries management (Moore et al., 2009). In many respects, fisheries management of this type - the ecological attributes of the coastal seascape - could be seen as analogous to more conventional management of the factory floor. It is here, on the coastal ‘factory floor’, that the products that will eventually be supplied to market have their origin. A photo of each these four coastal habitats can be seen in Table 4, which is followed by a brief description of each habitat.

Table 5. The four dominant habitat types characteristic of the Lipsi coastal seascape. Habitat photos 1, 2, 3 from author, 4 from Oceana Europe.

(1) *Posidonia oceanica* Seagrass Meadows	
(2) Rocky-Algal Formations	
(3) Un-vegetated Sandy Bottom	
(4) Coralligène Reefs	

Seagrass Meadows

Seagrasses are marine flowering plants that can cover large areas in shallow coastal waters; the meadows they form are amongst the most biologically diverse and productive habitats to be found in coastal ecosystems (Table 2) (Hemminga and Duarte, 2000; Telesca et al, 2015). The dominant seagrass species in the Mediterranean coastal zone is *Posidonia oceanica,* although occasional meadows of *Cymodocea nodosa* and *Halophila stipulacea* may be found within the canopy. *Posidonia oceanica* is characterized by a buried stem attached to a thick rhizome that extends beneath the surface. Leaves are long (<1000mm in places) and green in colour. Meadows form a complex three-dimensional habitat for faunal assemblages.

Rocky-Algal Formations

The rocky-algal habitats surrounding Lipsi are represented by a heterogeneous hard substrate with mixed rugosity; rich in crevices and other shelter (Table 2). This habitat is generally found immediately adjacent to the landmass and is characterized by a gentle slope. Rocky-Algal formations often exhibit a dense cover of macro-algae's, mainly Corallinaceae and Cystoseiraceae that extended <100mm from the substrate. The habitat also characterised by Dictyotaceae, Codiaceae, Cladophoraceae, Dasycladaceae, Liagoraceae, Udotaceae, Halimedaceae, and Polyphysacease on occasion.

Un-vegetated sandy Bottom

The sandy habitats constitute coarse sandy bottoms, generally void of vegetation (Table 2). However, in some instances clumps of the algae *Ulva rigida* or mats of the invasive algaes *Caulerpa prolifera* and *Caulerpa racemosa* combine to add some complexity to the habitat. In addition, loose rocks, marine debris and the invasive seagrass *Halophila stipulacea* can also be found in some areas, but with a maximum canopy height of 60mm this seagrass does little to alter the ecosystem structure and function

Coralline Reefs

There are two basic forms of coralline algae that are in the Mediterranean. The first form is similar to a minute reef and is 0.5m-4.0 m high (Laborel, 1987), which is found at depths between 40-130m (Table 2). The other one consists of surface films no thicker than a few centimetres interspersed with pebbles known as rhodoliths (Georgiadis et al, 2009). In rare cases this can reach depths of 160 m (Laborel, 1987). Due to the depth of these formations, their functional ecology is considered outside the scope of this thesis. However, they are identified and mapped through outreach to Traditional and Local Ecological knowledge in Chapter 5 and will be further mentioned as a targeted habitat for the Small-Scale Capture Fishery in Chapter 7.

CHAPTER 4 – Place-Based Conceptual Framework

4.1 Conceptual frameworks

Miles and Huberman (1994) defined a conceptual framework as a visual or written product, one that;

"explains, either graphically or in narrative form, the main things to be studied—the key factors, concepts, or variables—and the presumed relationships among them".

Miles and Huberman (1994, p.18)

Such frameworks represent only a 'model' of what exists, providing a tentative theory on the relationships between the phenomena under investigation. Conceptual frameworks inform both research design and management decisions, by enabling the development of *realistic* and *relevant* research questions, and the selection of *appropriate* methods so that internally valid and empirically justified conclusions can be drawn.

Developing a conceptual framework usually begins with 'concept mapping' (Novak and Gowin, 1984), a visual display of the theory as to what is 'going on' with the phenomenon under consideration. However, in this case, the conceptual framework being proposed is an extension and novel application of an existing concept - the supply chain - and its sustainable management.

A conceptual framework detailing the sustainability considerations for a place-based small-scale fishery "habitat to consumer" supply chain is the focus of this chapter, and forms the guiding structure of this research thesis and its results chapters; with each of the subsequent results chapters representing a stage of the proposed '*Habitat to Consumer'* supply chain.

4.2 Supply Chain Management (SCM)

In most businesses and industries today, the conceptualisation of consumer products and services as supply chains is now commonplace (Stadtler, 2015). From the extraction of the basic raw materials [natural resources] to the delivery of the final product to the consumer, each step in the production process is a link in the 'supply chain (Mentzer et al., 2001).

The supply chain concept has since been popularised through many applied and research fields, and such divergent research interests have also led to a range of terminologies used to describe the supply chain concept: these include 'demand pipelines' (Farmer and Van Amstel, 1991), 'value streams' (Womack and Jones, 1994) 'support chains' and many others (see Chen and Paulraj, 2004). The origins of the proposed 'management' of these supply chains are unclear. Popular culture attributes the growth of logistics to the mass production of the Model T Ford beginning in 1927, although more formally, the business and management literature points to the research into physical distribution and transport. A field of research that has its origins in the work of Forrester (1958):

"Management is on the verge of a major breakthrough in understanding how industrial company success depends on the interactions between the flows of information, materials, money, manpower, and capital equipment. The way these five flow systems interlock to amplify one another and to cause change and fluctuation will form the basis for anticipating the effects of decisions, policies, organizational forms, and investment choices."

Forrester, 1958

The initial work into the management of supply chains can also trace its origins to the 'total cost approach' of distribution and logistics (Heckert and Miner, 1953; Lewis 1956). Either way, both bodies of research show that just focusing on a single element in a 'supply chain' cannot assure effectiveness of the whole system (Croom et al, 2000), or in this case, a coupled socio-ecological system. What is highlighted is the need for management measures at *every stage* of the supply chain. In discussing the shape of the future, Forrester (1958) also remarked that:

"there will come general recognition of the advantage enjoyed by the pioneering management who have been the first to improve their understanding of the interrelationships between separate company functions and between the company and its markets, its industry, and the national economy."

Forrester, 1958

Although this article is over fifty years old, Forrester identifies the key management issues and illustrates the dynamics of factors associated with the phenomenon referred to in contemporary business literature as Supply Chain Management (SCM). This term seems to trace its origins from applied work, and reports by consultants working in the early 1980s (Oliver and Webber, 1992). However, it was not long before the term (and concept) had become commonplace in the research literature (La Londe, 1996). Analytically, a typical supply chain (Figure 50) is a network of materials, information and services processing links with the characteristics of supply, transformation and demand (Chen and Paulraj, 2004).

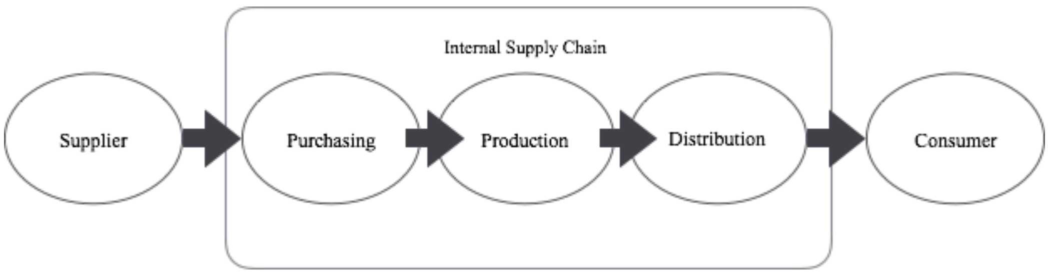


Figure 26. A 'typical' companies supply chain (Chen and Paulraj, 2004).

SCM incorporates the whole set of events from extraction / production, to transformation and distribution, and eventual consumption. This process has also been referred to as Demand Chain Management (DCM) to emphasize the focus on meeting consumer expectations (Heikkilä, 2002). SCM and DCM may be characterised as the upstream and downstream orientations of management respectively (Bustinza et al, 2013).

The desired management of supply chains aligns well with 'stakeholder theory'

(Donaldson & Preston, 1995; Freeman, 2010) since capturing all of a chain's impacts can inform how they affect all stakeholders. However, as Clarkson (1995) discussed, there is not typically universal agreement between stakeholders on supply chain issues, and thus the proposed 'management' of supply chains can often be to different ends, depending upon the priorities of those doing the managing!

Numerous studies have reviewed research on SCM, primarily with the aim of identifying its 'boundaries' or 'core features'. In some cases, this has been perceived as an attempt to promote SCM research as a distinct 'field' or 'discipline' within management research (Croom et al., 2000; Harland et al., 2006). Most reviews have concluded that SCM research is in its infancy relative to other fields of business and management research, and thus is currently characterised by a relative absence of (1) theoretically informed research and (2) a large amount of empirical research (Brammer et al., 2011).

In isolation, the SCM field appears to focus on the economic performance of the supply chain, rather than its performance as a component of the Triple Bottom Line (3BL). However, whilst efficiency, competitiveness and profitability have been the core drivers of supply chain research and development, recently several reviews have focused on 'sustainability and its relationship to SCM'. These reviews have generally confined their attention to environmental issues (see Srivastava, 2007; Sarkis et al., 2011) and have thus been considered as examples of 'Green Supply Chain Management' (GSCM).

Two GSCM reviews in particular have paid attention to the conceptual features and orientations of prior research, which suggests that theories from broader operations management and organisation literatures may well contribute significantly to the future development of GSCM (Brammer, et al., 2011). Here the GSCM field appears to focus on the environmental and economic performance of the supply chain and thus only two dimensions of the TBL.

Finally, two other reviews (Carter and Rogers, 2008; Carter and Easton, 2011) focus on the broader literature concerned with Sustainable Supply Chain Management (SSCM). Despite the contested views and ambiguity of SSCM as a term and concept that emerges, the term SSCM should incorporate all three dimensions of 'sustainability'; the social, the environmental and the economic performance. The evolution of focus and shifting trends in the field of SCM can be witnessed in the 'most prevalent issues' in international sustainable supply chain research in three periods as compiled by Brammer et al. (2011) for the Network for Business Sustainability (Table 5)

Table 6. Most prevalent issues in international supply chain research in three periods (from Brammer et al., 2011)

Before 2003	2003-2006 Inclusive	Since 2007
Generic "Green" or Environmental Issues	Working Conditions	Working Conditions
Human Rights	Generic "Green" or Environmental Issues	Generic "Green" or Environmental Issues
Child Labour	Human Rights	Sustainability
Working Conditions	Low Wages	Human Rights
Bribery	Corporate Social Responsibility	Low Wages

4.3. Sustainable Supply Chain Management (SSCM)

Recent transdisciplinary moves towards GSCM and SSCM is helping to restructure the narrative towards the resilience of ecological systems on which socio-economic supply chains depend (Seuring, 2013, Stadtler, 2015), a move that has been bolstered by current criticisms from within the business and management literature that '*the development of sustainable supply chain management (SSCM) theory has been impaired by a lack of paradigmatic diversity in the field'* (Matthews et al., 2016) and that SSCM research needs to focus on actually '*Making Sustainability Sustainable'* (Montabon et al., 2016).

This refocusing, and revisiting of traditional supply chain concepts is helping to refocus the lens on SSCM, but presently a universally agreed 'working definition' for SSCM is still elusive. It is suggested here that Seuring and Müller's (2008) definition captures the essence of SSCM as it is currently perceived:

"Sustainable SCM is the management of material, information and capital flows as well as cooperation among companies along the supply chain while integrating goals from all three dimensions of sustainable development, i.e., economic, environmental and social, which are derived from customer and stakeholder requirements. In sustainable supply chains, environmental and social criteria need to be fulfilled by the members to remain within the supply chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria."

Seuring and Müller (2008)

The ambition of 'meeting customer needs' and related 'economic criteria' has situated the SSCM field in an Economically Dominant Research Logic (Matthews et al, 2016; Montabon et al., 2016). Under this paradigm, global supply chains have played a principal part in ecological degradation as social and economic [manufactured] capital replaces natural capital (Matthews et al., 2016). Within the fishing industry this management paradigm is crucial because of the industry's increased capacity to completely erode the natural resource base (natural capital) and thus the very existence of the supply chain itself.

This has led some authors to position 'sustainability' as a moral question, since it concerns both present challenges and the legacy for future generations (Speth, 2008; Matthews et al., 2016). Indeed, the scarcity of natural resources is of immediate concern across economic, industrial and political systems, where concerns are increasingly expressed over even the short-term availability of natural resources (Matapoulos et al, 2015).

It is acknowledged that the modern era of globalisation has had profound implications for managing companies at the strategic and operational levels (Brammer et al., 2011). Central to these challenges has been the dramatic growth in the *"cross-border movement of goods and the emergence of global competitors and* *opportunities across competing supply chains within an industry"* (Mentzer et al., 2007). Several industry specific studies have analysed the supply chain sustainability of leading global firms such as; GAP, and their alleged links to child labour in the 1990s; Apple and working conditions in the 2000s; and most recently (2014) Coca-Cola, and their reported links to exacerbating local water shortages in India. A recent literature review of the industries featuring prominently in such studies, include textiles (incorporating apparel and sporting goods), retailing, food and drink (including coffee and tea), and electronics (see Brammer et al., 2011).

The Economically Dominant Research Logic for much of this previous work on these industries supply chains has generally asked the question *"How can a supply chain benefit from addressing environmental or social issues?"* (Garriga and Melé, 2004; Gao and Bansal, 2013;) as opposed to the more fundamental question of *"How can a supply chain become more sustainable?"* (Montabon et al., 2016). This position is evidenced by the number of literature reviews on the link between sustainability and economic performance (e.g. Orlitzky et al, 2003; Barnett and Salomon 2012; Golicic and Smith, 2013) where the relationship of interest in these reviews are explicit tests of instrumental logic i.e. where one variable e.g. becoming more environmentally responsible, influences another, such as 'profits'.

There have been previous attempts to reposition research away from an Economically Dominant research logic. The Natural Resource Based View (NRBV) was proposed over twenty years ago by Hart (1995) as an integrative theory of sustainability with the natural environment as a key constraint; and yet a recent follow up by Hart and Dowell (2011) noted that despite this earlier contribution, research today was still too focused on the short term economic gains from 'being green' rather than supply chain sustainability. This has led some researchers (e.g. Matthews et al., 2016; Montabon et al., 2016) to champion an alternative "Ecologically Dominant" (ED) research logic, that first prioritises the protection of the environment (natural capital), then society (social capital), and only lastly the economy (economic capital). After all, it is an ED logic that forms the basis for research into coupled socio-ecological systems and the associated school of 'resilience' research (Folke et al., 2003; Berkes 2007) and therefore much can be learnt from a transdisciplinary approach to merge these schools of thought.

4.4 An Ecologically Dominant Research Logic

The dominant assumption within SSCM appears to be that economic, environmental and social sustainability can be achieved simultaneously (Matthews et al., 2016), but the concern here is that such an approach legitimises business and management practices that make short term "business sense" [i.e. economic sense], rather than considering other non-economically focused approaches which have been both 'radical', and ironically, 'unsustainable' (Pagell & Shevchenko, 2014). For example, it has long been discussed within the economics literature that sustainability will require 'painful trade-offs' (Barbier, 1987; Ekins, 2003), and indeed trade-offs in sustainability are emerging as a research theme (e.g. Hahn et al., 2010).

Whilst the evidence that firms are attempting to become 'more sustainable' (or less unsustainable!) is mounting (Carter and Rogers, 2008; Brammer et al., 2011) the trend towards compensation practices (e.g. carbon offsetting) does not create truly sustainable supply chains (Montabon et al., 2016). These practices merely serve to reduce a supply chain's negative impact either on society or the environment (or both) and thus perpetuate an Economically Dominant mode of thinking. For this reason, Matthews et al. (2016) have called for a paradigm shift within SSCM so that we can theorise about how SSCM can '*contribute towards the transition to sustainability through the protection of natural capital'*, a motivation echoed by Montabon et al. (2016) who seek to move the field of SSCM beyond the question of how can firms merely diminish environmental or social problems.

Table 6 and Figure 51, adapted from Montabon et al. (2016) summarises the questions asked by both the 'Economically' and 'Ecologically' dominant research logics highlighting the need for long term versus short term thinking and the need for a nested approach to supply chain management decisions. Under an Ecologically Dominant research and management paradigm SSCM has the potential to be a "locus for change" and make positive contributions to the preservation of global ecosystems (Mohrman and Worley, 2010), something that will require a multi-disciplinary approach (Seuring, 2013).

Table 7. Comparison of Current 'Economically Dominant' and Proposed 'Ecologically Dominant' logics (adapted from Montabon et al. 2016)

	Economically Dominant	Ecologically Dominant
Relationship among environmental, social, and economic	All are equal – efforts that create shared value or which are less unsustainable are acceptable	The three are nested. Need to satisfy environmental, then social prior to economic.
Time horizon	Short	Long
Practical reality	Satisfies customers' expectations while doing *least* amount of harm.	Does *no* harm while satisfying customers' expectations.
Outcome	Organized irresponsibility / tragedy of the commons	Integrated sustainable supply chains
Cognition – managers	"If it's not profitable you don't do it."	"If it harms the environment or society you don't do it."
Cognition – researchers	Does it pay to be green? Looking for win / win outcomes. Efficiency (Gross Domestic Product)	How to be profitable while doing no harm Conservation. Well-being (Gross Domestic Happiness)

In fact, sustainable SSCM must encompass a range of disciplines from economics (marketing, logistics, and organisation behaviour) to sociology (culture, policies, institutions and processes) and ecology (productivity, sustainability, resilience) (Seuring, 2013). In this thesis, the *supply and purchasing process* is considered in terms of the SSCM processes of capture fisheries as an extractive industry from coastal habitats (the suppliers). The research logic is configured by a hierarchical conception of the ecological, social and economic systems. A nested "three pillars of sustainability" and therefore an ecologically dominant (see Montabon et al., 2016) research logic. Under this logic, when trade-offs are inevitably encountered the priority is to protect the environment, then society and only then to consider profits. In this light, the following [and adapted] broad definition of SSCM is proposed for this thesis:

"Sustainable SCM is the pursuit of sustainability objectives through the purchasing and supply process, incorporating social, economic and environmental elements…

Walker and Jones (2012)

…and where any trade-offs consider first the environment, then the society, and only lastly the economy.

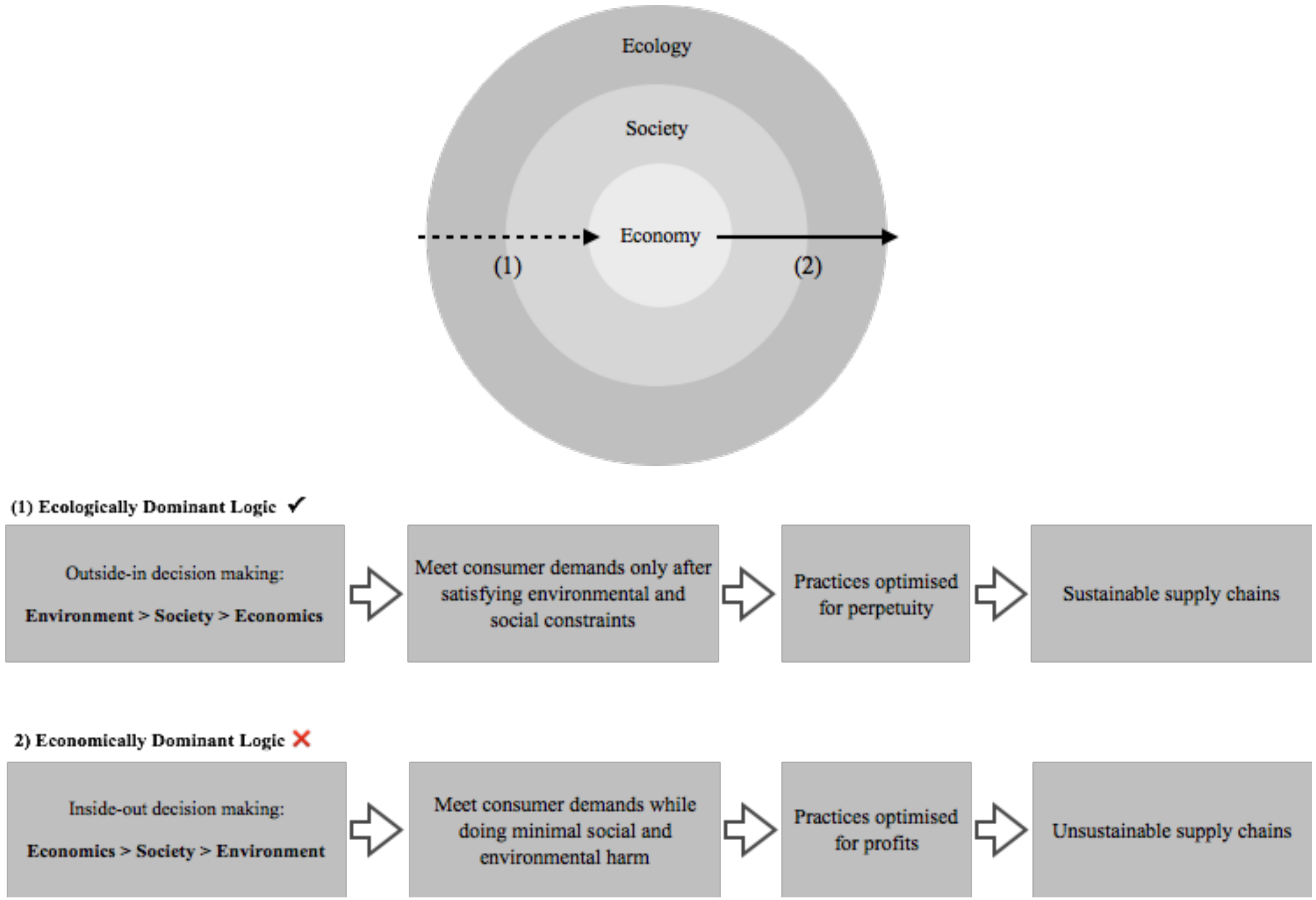


Figure 27. The nested three pillars of sustainability illustrating the conflicting cognitions of Economically and Ecologically dominant logics

4.5 Ecologically Dominant Sustainable Supply-Chain Management in Small-Scale Capture Fisheries

There have been moves towards standard setting and governance in fisheries in response to declining resources (Phillips et al., 2008). However, despite calls to make the seafood industry more sustainable through creating production chain transparency and accountability (Iles, 2006; Iles, 2007), little progress has been made in providing a pre-catch supply chain framework. Under the present United Nations Food and Agricultural Organisation (FAO) 'Catch to Market' supply chain conceptual framework, 'nature' (habitats and species assemblages), is assumed to be homogenous and indefinite. It therefore ignores the *pre-catch* availability of natural resources (i.e. the ecological system) as a 'Catch to Market' (socio-economic system) supply chain risk factor. What is needed is a more holistic framework which looks at drivers of extraction before 'Catch'. Where specifically in 'the sea' does the seafood, product originate? Which habitats are involved in seafood production? What balance of species are needed to keep the habitat productive?

Generally, any attempt to make a supply chain more sustainable will need to target producers explicitly (supply side management) (Iles 2006) and educate consumers in sustainable seafood choices (demand side management) (Jefferson et al, 2015). However, for SSCM to be effective at sustaining the availability of natural resources (Matapoulos et al, 2015), consideration must be paid to each stage in the chain; a coupling of both upstream and downstream orientations (Bustinza et al, 2013), with an appreciation of the feedback loops operating within those natural resource supply chains that span coupled socio-ecological systems (Folke, 2006).

Supply Side Management

Supply side management has traditionally been under the jurisdiction of regional and national governments, with fisheries management characterising a global suite of legal and voluntary codes of conduct that are unique to place. Here fisheries supply chain management generally only refers to the supply chain stages in the ecological system, and is defined as:

"The integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives"

FAO, 1997

Here, management controls will typically restrict the quantity of fish that can be landed, and the conditions for doing so (e.g. size, season, area). Such controls have also paralleled the development of Marine Protected Areas (MPAs) and other 'area based' management initiatives which rely on effective policing as a 'command and control' approach to regulation (Whitmarsh, 2013).

Demand Side Management

Demand side management, by contrast, is under the jurisdiction of the Socio-Economic system whereby retailers (i.e. restaurants, fishmongers, supermarkets) in the seafood market are pressured to source seafood that is sustainably produced. End consumers are also educated to demand sustainable seafood products. Here fisheries supply chain management involves:

"…raising consumer awareness of the environmental attributes of fisheries products, in order to influence their purchasing decisions."

Whitmarsh, 2011

An example of a demand side scheme is the Marine Conservation Society's "Good Fish Guide" (Figure 52) that encourages consumers to "*avoid eating fish in the red list, enjoy eating fish in the green list and only occasionally eat fish from the amber list."* These lists simplify consumer choice and promote the consumption of sustainable seafood through increasing demand for more sustainable species.

Figure 28. The Marine Conservation Society's "Good Fish Guide" offers a traffic light system of sustainable seafood.

Managing both Supply and Demand

There have been some attempts to address supply and demand drivers simultaneously. These certified fisheries schemes, such as those of the Marine Stewardship Council (MSC) (Figure 53) often go beyond voluntary codes of conduct and self-regulatory modes of governance and instead have involved prescriptive standards which require behavioural changes and independent verification of compliance (Gulbrandsen, 2009). Seafood products originating from fisheries certified as ‘sustainable and well managed’ are awarded an eco-label. Instead of providing consumers with information about a range of products (i.e. the Good Fish Guide), consumers can simply choose to purchase products identified as ‘sustainable’ to them via the MSC eco-label. Under this model, the certifying organisation determines whether producers are (supply side) sustainable and the consumers must depend on their judgement. Such recognition is expected to translate into market benefits via a price premium for products bearing the MSC logo. The scheme thus incentivises SSCM by the prospect of higher returns.

Figure 29. The MSC eco-label is the only independent global fish certification scheme.

However, such schemes have limitations, particularly for diverse, small-scale and subsistence fisheries. Such fisheries may have significant ecological and social impacts but can be marginalised because they do not fit MSC's management model (Iles, 2006). This risks numerous small-scale decentralised fisheries in developing countries being discriminated against, because they cannot bear the costs of certification and do not have the capacity to implement certification requirements. Many fishers are excluded from considering MSC certification because of the actions of others that are beyond their control (Kaiser and Edwards-Jones, 2006) with fisheries in developing countries under-represented in the programme (Guldbransen, 2009).

In addition to model problems, such schemes must decide if the principles and criteria for certification should only address fishing operations and environmental issues, or if they also should address social and development issues (Auld, 2007). Much of this debate has surrounded the socio-economic aspects of fisheries management, particularly pertaining to the needs of fish workers and SSCF in developing countries (Ponte, 2007). So how do we judge the sustainability of these small-scale fishery supply chains? Fundamentally, for place-based SSCM it is the combination of supply and demand side instruments that are required to tackle unsustainable fishing practices. Table 7 presents a typology of key measures employed to attempt to manage marine capture fisheries supply chains.

The table distinguishes between management measures that are 'supply side' controls on fishing activity (involving legislation and subsequent policing) and those that are 'demand side' instruments (involving fishers and consumers), and those that are both. Crucially, demand side measures are only as effective as the supply side controls on which they are predicated. If supply side controls are weak in the face of increased demand, and fishing pressure is not contained, then the long-term benefits of supply chain management are unlikely to be durable. As Whitmarsh (2011) argues: *"demand side measures such as eco-labelling make the need to solve the open-access problem more imperative, not less"*. However, if supply-side management measures are strong, demand-side approaches such as eco-labelling at least offer fishers potential personal gains from cooperating in the fisheries management process.

Table 8. A typology of some of the management measures that have been introduced in an attempt to make marine capture fishery supply chains more sustainable.

APPROACH	MEASURE	EXAMPLES
Supply Side	Extractive output	Total allowable catch (TACs) Maximum Sustainable Yield (MSY)
	Licensing	Fleet size / fleet power / days at sea Gear type (e.g. offshore / coastal / sport)
	Spatial Planning	Marine Protected Areas (MPAs) Marine Exclusion Zones (MEZs)
	Temporal Planning	Closed Seasons Temporary Seasons
	Technical	Mesh size / hook size / gear type Minimum landing size (MLS)
	User rights	Territorial User Rights (TURFs) Individual Transferable Quotas (ITQs)
	Price controls	Set pricing for landed fish e.g. Norges Råfisklag (organized monopolies)
Demand Side	Consumer awareness	World Wildlife Fund (WWF) Fish Fight Campaign
	Traffic lighting	Marine Conservation Society (MCSUK) World Wildlife Fund (WWF)
Both	Eco-labelling	Marine Stewardship Council (MSC) and Aquaculture Stewardship Council (ASC)

Global experience in dealing with the problems of common pool resources suggests that a 'one size fits all' approach is unlikely to be found, since the institutional arrangements that work well in one place may fail in others (Ostrom, 2008). For this reason, place-based research frameworks (such as the one presented here) can be crucial in identifying localised challenges to seafood supply chain sustainability.

The focus of this thesis is to addresses these challenges to sustainability through a place-based study of a Small-Scale Capture Fishery (SSCF) in Greece; specifically the seafood supply chain of The Municipality of Lipsi. It is to be achieved by a place-based, transdisciplinary approach that harnesses the developments in coupled Socio-Ecological Systems (SES) research, and uses them to support the proposed 'Ecologically Dominant' (ED) Sustainable Supply Chain Management (SSCM) Conceptual Framework (CF). (Figure 54).

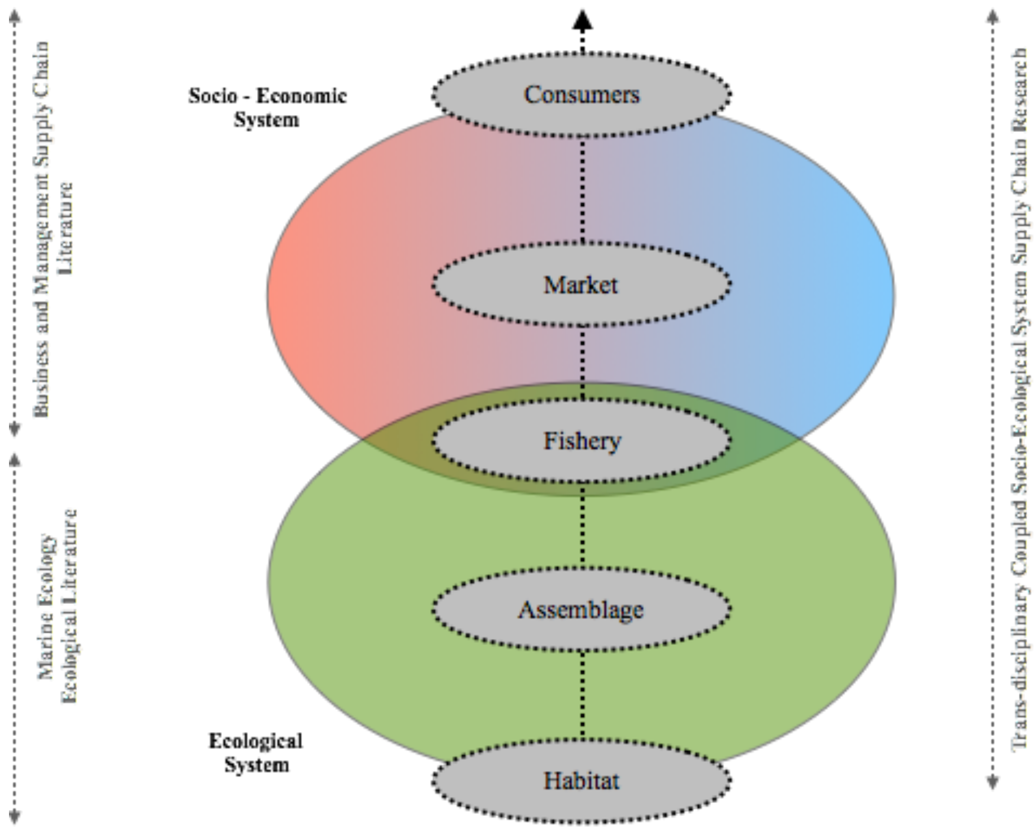


Figure 30. Business supply chains span socio-economic and ecological systems. Transdisciplinary research rooted in an ecosystem based management approach is required to couple complementary approaches to sustainable supply chain management including both Biological (pre-catch) and Business (catch to market) management measures

4.6 'Habitat to Consumer' supply chain thinking in Small-Scale Capture Fisheries

"Farm-to-fork" is typically the term which refers to the supply chain stages of the production of terrestrial food, incorporating every step in the process (EC 2000; http://ec.europa.eu/food): harvesting, storage, processing, packaging, sales and consumption. The term can equally apply to aquaculture where "Farm to Fork" supply chains (including marine fish farms) can document the supply chain from its beginning, including feed and habitat inputs. This is because both the habitat and the inputs of species assemblages within it are controlled.

Supply chains in marine captures fisheries are not generally articulated in the same manner. Here, traditional "Catch to Market" supply chains do not consider the ecosystem (habitat and assemblage) contribution to the creation and development of the seafood product, beginning the conceptualisation of the supply chain at the extraction of the seafood product (Figure 55).

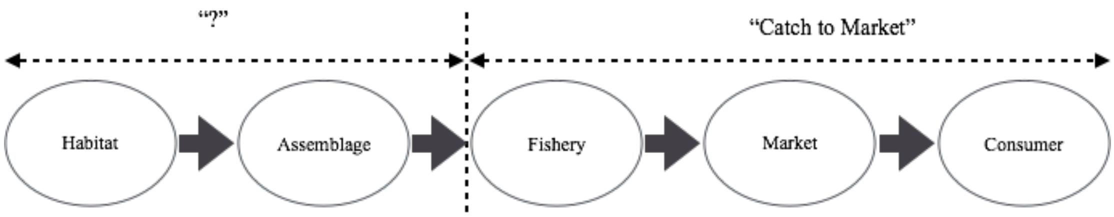


Figure 31. A capture fisheries supply chain. Traditional "Catch to Market" thinking takes no account of the supply chain (ecological system) pre-harvest, only considering the supply chain post-harvest (socio-economic system).

Inputs into marine capture fisheries reflect the pre-catch 'life history' (entire life cycle) of consumed seafood species and the ecosystems on which they depend. Only through acknowledgment of the heterogeneity of the marine environment (different habitats within a seascape) can we better understand the contributions of individual habitat types to the supply chain (or indeed key species, within an associated species assemblage, to ecosystem structure and function). Only through approaching seafood supply chains from a 'Habitat to Consumer' perspective will supply chain traceability become practicable. We need to start asking, what is the supply chain pre-catch?

To understand the Habitat to Consumer supply chain requires multidisciplinary research and data collection: SSCM needs to look beyond the socio-economic drivers (*consumer* and *market*) that shape the behaviour of the *fishery*, to include the ecological system (*habitat* and *assemblage*), that also shapes the behaviour of the *fishery*. This can be done by determining the presence (or absence) of species in particular habitats. Achieving this will only be possible through making the theory and key constructs, variables and relationships explicit through a fully articulated and coherent 'Habitat to Consumer' supply chain.

The 'Habitat to Consumer' framework proposed herein essentially equates to the 'producer' to 'supplier' in a typical company's supply chain (Figure 55). An immediate risk factor to the supply chain is therefore the sustainability of the relationship between the 'Internal Supply Chain' (the extent and means of extraction of seafood products by the small-scale fishery) and its suppliers (coastal habitats); principally how it goes about replenishing (fishing) from its supplier. In addition, for successful SSCM using this conceptual framework, attention must be paid to the 'condition' of the seafood products provided to the market by the fishery. Whilst desired seafood products might well be present in the species assemblages associated to specific seascape habitats, the 'condition' of the product provided might not meet basic sustainability standards. For example, a simple criterion for sustainable seafood supply chains is the extraction of seafood species that have had the chance to reproduce (are above the species length at maturity), and therefore the supply of juvenile seafood products to the market would represent the provision of an "unfinished" product. From a demand side perspective, the '*consumer*' and the '*market'* reflects the socio-economic system and is equivalent to the FAOs current "catch to market" supply chain thinking.

A five-stage (Habitat-Assemblage-Fishery-Market-Consumer) supply chain conceptual framework is presented here in Figure 56, and articulated beneath from the point of view of a novel SSCF SSCM framework. This framework represents an exemplar 'step by step guide' of the key considerations that researchers and managers could include for an interrogation of the sustainability of a given SSCF, in any given place (Table 8).

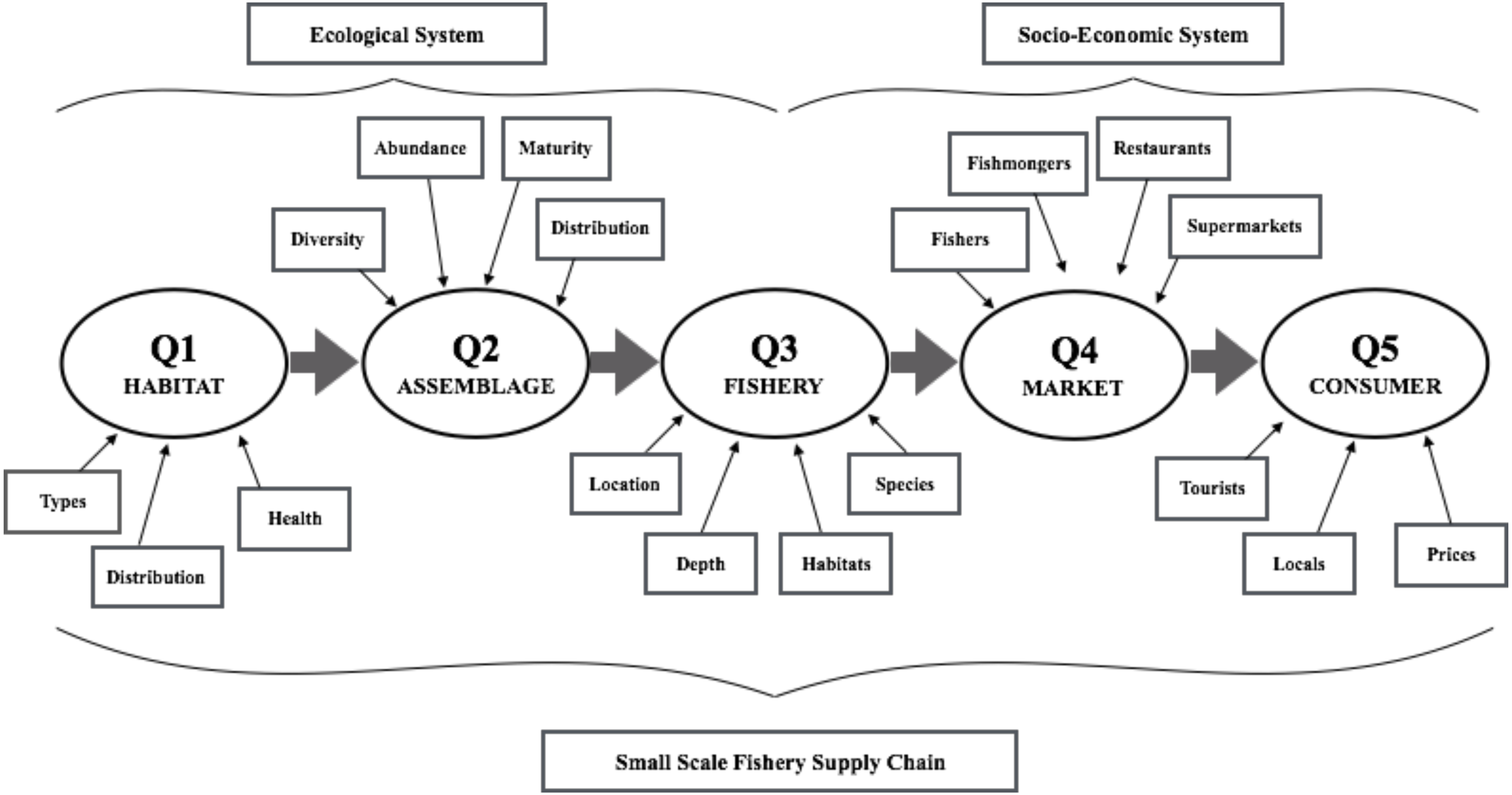


Figure 32. The "Habitat to Consumer" five stage process for interrogating a small-scale fishery supply chain. The SSF spans and connects both the ecological and socio-economic system.

Table 9. A place-based "Habitat to Consumer" supply chain conceptual framework: incorporating Habitat, Assemblage, Fishery, Market and Consumer considerations.

Stage	Considerations	Methods
Habitat	Define the ***habitat*** Coral Reef Seagrass Rocky Reef Kelp Forest Sandy Bottom Mangrove Coralligène	Quantify the habitat ***size*** and ***distribution.*** Remote Sensing Satellite Imaging Unmanned Aerial Vehicle Quantify the habitat ***health***. % Cover / Bio-indicators Species presence / absence Disease
Literature Examples: Bekkby et al., 2008; Ehler and Douvere, 2009; Chust et al., 2010; Sundblad et al., 2014, Koedsin et al., 2016; Warren et al., 2016; Barrell and Grant, 2015)		
Assemblage	Define the ***assemblage*** Faunal density Faunal diversity Faunal maturity	Quantify assemblage ***association*** and ***connectivity*** Nursery-role hypothesis Ecosystem-connectivity Spatial patterning Quantify ***food web interactions*** Predator-Prey Interactions Feedback loops Trophic roles
Literature Examples: Nagelkerken et al., 2000; Beck et al. 2001; Nagelkerken, 2007; Boström et al., 2011; Lilley and Unsworth., 2014; Nagelkerken et al, 2015; Jokinen et al., 2015)		

Fishery	Define the ***fishery*** Size Gears Spatial Temporal	Quantify fishing pressure by ***landings*** and ***bycatch*** Faunal species diversity Faunal species abundance Faunal species maturity (Lm) Quantify ***environmental impact*** Habitat loss Species loss Temporal trends

Literature Examples: Cooke et al., 2004; Tzanatos et al., 2005; Tzanatos et al., 2006; Nordlund et al., 2010; Lloret and Font, 2008; Unsworth et al., 2014; Cullen-Unsworth et al., 2014

Market	Define the ***infrastructure*** *(choice capacity)* Supermarket Fishmonger Fisher	Quantify ***availability*** (*choice task*) *and* ***presentation*** (*choice options*) Choice of species (i.e. what to present to consumers) Presentation of species (i.e. how choice is presented)

Literature Examples: Larrick and Soll, 2008; Scheibehenne et al., 2010; Johnson et al., 2012; Balz et al., 2014; Sunstein and Reisch, 2014; Smith et al., 2016)

Consumer	Define the ***demand (consumer)*** Age Nationality Wealth	Quantify ***social*** *and* ***economic*** *drivers* Price of species ***Cultural*** perception of species (traditional and culture)

Literature Examples: Castilla and Fernandez, 1998; Hall et al., 2003; Everett and Aitchison, 2008; Cullen-Unsworth, 2010; Béné et al., 2010; Cinner et al, 2012; Horner and Swarbrooke, 2016

4.6.1 Habitat to Consumer Supply Chain Stage 1 – Habitat

Q1 = Habitat Questions

Q1a – What are the coastal habitats?
Q1b – What is the relative extent and distribution of habitats in the seascape?
Q1c – What is the biological health of the habitats?

Within the Habitat to Consumer supply chain the 'Habitat' stage refers to the physical environment of the ecosystem (minus faunal assemblages). Habitats might be defined as a 'seagrass meadow' or 'coral reef', but these habitats together will form a 'seascape' (a variety of habitats together) or a 'habitat mosaic' (Nagelkerken et al., 2015). To define the 'suppliers' in the supply chain it is essential to define the habitats that make up the seascape. There are two key and inter-linked considerations; the contributing habitats '*size and distribution'* and the habitats '*health'*.

Seascape connectivity is essential for marinating viable populations, especially against the backdrop of habitat degradation linked to global climate change (Cobben et al., 2012). With increasing stress from global processes, scientists and resource managers are looking to larger-scale methods of ecosystem assessment (Mumby and Edwards, 2002). Habitat-linked species connectivity has been well documented in terrestrial landscapes where some species are restricted to fragmented habitats or are naturally arrayed in meta-populations (Taylor et al., 1993). Accurate mapping of seascape 'place' at the geomorphological scale (e.g. coral vs seagrass) is therefore critically important. However, until the last few decades, limitations in remote sensing technology have prevented effective mapping of place at the habitat patch scale since pixel sizes of 20–30m were of a similar magnitude to the size of habitat patches (Mumby et al., 1999). Presently, the importance for assessing both structural connectivity (the physical habitat patches) for managing such species is well understood, with researchers identifying that complex interactions among multiple factors may produce highly individualistic response to threats, both across species and places (Rapacciuolo et al., 2014; Castillo et al., 2016; Schwalm et al., 2016).

For species with naturally fragmented distributions (either associated to a specific habitat type), or that exist in meta-populations (are connected across multiple habitat patches in a given area), predictions of population persistence based on patch characteristics alone will ignore the possibility that a loss of between-patch connectivity. Such connectivity loss between individual populations could lead to meta-population collapse, and ultimately therefore extirpation / local extinction (Castillo et al., 2016).

At the beginning of an SSCF supply chain, the species that will become the 'final seafood product' is in its raw form, and its condition will depend upon the quality of inputs from the habitat, or habitats, in which they grow and develop. Like other natural resources, the productivity of the habitat (supplier) is subject to externalities. Supply side variability in fish quantity and quality can be influenced by season, climate and weather (Harmelin-Vivien, 1994, Turpin and Bortone, 2002). Furthermore, stochastic events (e.g. hurricanes), or human induced regime shifts (e.g. coral reef to algal rubble) will profoundly affect the resilience of the ecosystem and its capacity to provide goods and services (Hughes et al., 2010; Costanza et al., 2014; Unsworth et al., 2015).

Size and distribution

'Size and distribution' together consider the geo-spatial pattern of habitats in the ecosystem, for example the size and shape of a coral reef or seagrass meadow, in relation to the benthic sandy substrate (Figure 57).

Figure 33. A birds-eye view of a coastal seascape. Seagrass, sand and rocky-algal habitats are present in this photo (Photo 23-06-2015).

These variables are also key for deterring the geographic extent of the habitat (Mumby and Edwards, 2002, Roelfsema et al., 2014). Knowing the size and distribution of a habitat is key to SSCM since, for example, seagrass meadows support a greater abundance and diversity of fish (Ferrell and Bell, 1991, Jenkins et al, 1997) than adjacent bare sand habitats.

Health

'*Health'* considers the relative biological condition (Figure 58) of the habitat under consideration (see Hughes et al., 2010 for coral reefs; Unsworth et al., 2015 for seagrass meadows). For example by asking questions such as, 'Is the coral reef physically damaged?' 'Are the corals bleached?' Or 'Is the seagrass meadow patchy and scarred from anchoring?'

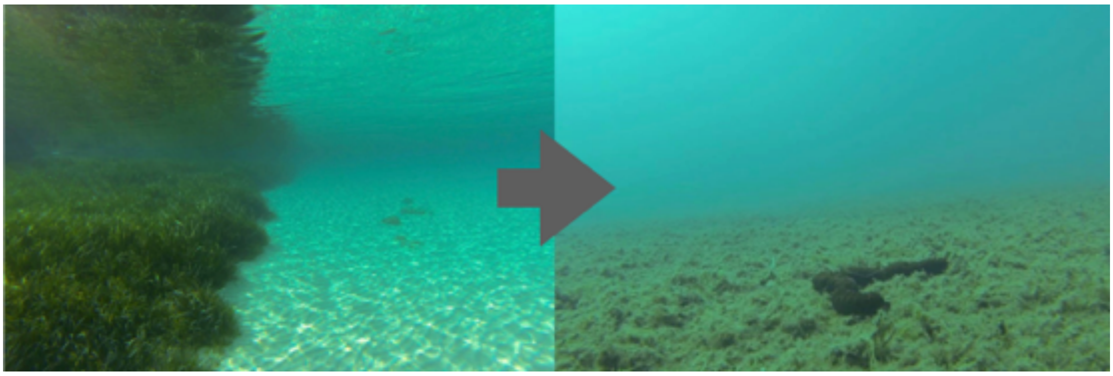


Figure 34. Stressors such as poor water quality can cause habitats to undergo regime shifts.

Bio-indicator approaches have highlighted the perilous state of some of the coastal dominant habitat forming species (Jones and Unsworth, 2016). Poor quality habitat status puts their long-term existence in doubt and reduces their ecosystem service value (fisheries' productivity). Others have demonstrated that larger and more intact habitats generally support greater biodiversity (McCloskey and Unsworth., 2015), and so the size and distribution of habitats are mediated by their physical integrity.

From a Habitat to Market supply chain perspective, such knowledge is critical, since large, connected and healthy habitats will increase the productivity of seafood in small-scale fishery supply chains (Nagelkerken et al., 2015).

4.6.2 Habitat to Consumer Supply Chain Stage 2 – Assemblage

Q2 = Assemblage Questions

Q2a – What are the species present in the coastal habitats?
Q2b – How many individuals are there?
Q2c – What is the condition of the individuals present?

The secondary stage of the Habitat to Consumer supply chain is the '*Assemblage'*. Within the Habitat to Consumer supply chain this stage is used to refer to the faunal assemblages that are associated with habitat types. The species assemblage associated with any given habitat will relate to the characteristics of the habitat in question. Some large transient species, such as Bluefin Tuna (*Thunnus thynnus*) will not typically utilise any coastal habitat type; yet other demersal species such as the Mediterranean Parrotfish (*Sparisoma cretense)* may associate with one or more habitat type. Such patterns are unique to place and understanding them is critical if we are to move beyond treating the sea as a homogenous entity. There are two key and inter-linked considerations; the contributing habitats *'association and connectivity'* and '*food web interactions'*.

There are currently three lines of research tackling the issue of coastal ecosystem connectivity for marine fauna, but at different conceptual scales (see Nagelkerken et al, 2015). Firstly, the *nursery role hypothesis* focuses on identifying habitats that contribute the most to adult populations (Beck et al, 2001; Nagelkerken et al., 2009; Lilley and Unsworth, 2014). Secondly *ecosystem-connectivity* studies attempt to correlate coastal nursery habitats to fisheries catch (Manson et al., 2005). Thirdly, seascape studies investigate the *spatial patterning of faunal communities* in coastal habitats (Guidetti 2000; Sheaves and Johnston, 2008).

Research suggests that only a few species are confined to a single habitat (Nagelkerken et al., 2007) and instead will utilize a mosaic of habitats daily (Boström et al., 2011), with the final migration of juveniles to join the adult population still poorly understood (Gillanders et al., 2003).

'Food Web Interactions' in marine ecosystems have been altered through a history of exploitation of top-predators, and this has been shown to alter ecosystem (both habitat and assemblage) function through direct and indirect pathways (Eklöf et al, 2008; Estes et al, 2011).

Association and connectivity

'Association and connectivity' of species assemblages to habitats is often the focus for marine ecologists, with multiple studies reporting the species assemblages associated with given habitats at various temporal and spatial scales (Guidetti 2000; Unsworth et al., 2008; Kalogirou et al, 2010). Such knowledge has been deemed essential when proposing EBFM initiatives, especially when there is evidence to show that connectivity between habitats in a seascape can affect both the size and density of fish (Mumby et al., 2004) or indeed the presence of certain species at all (Figure 59).

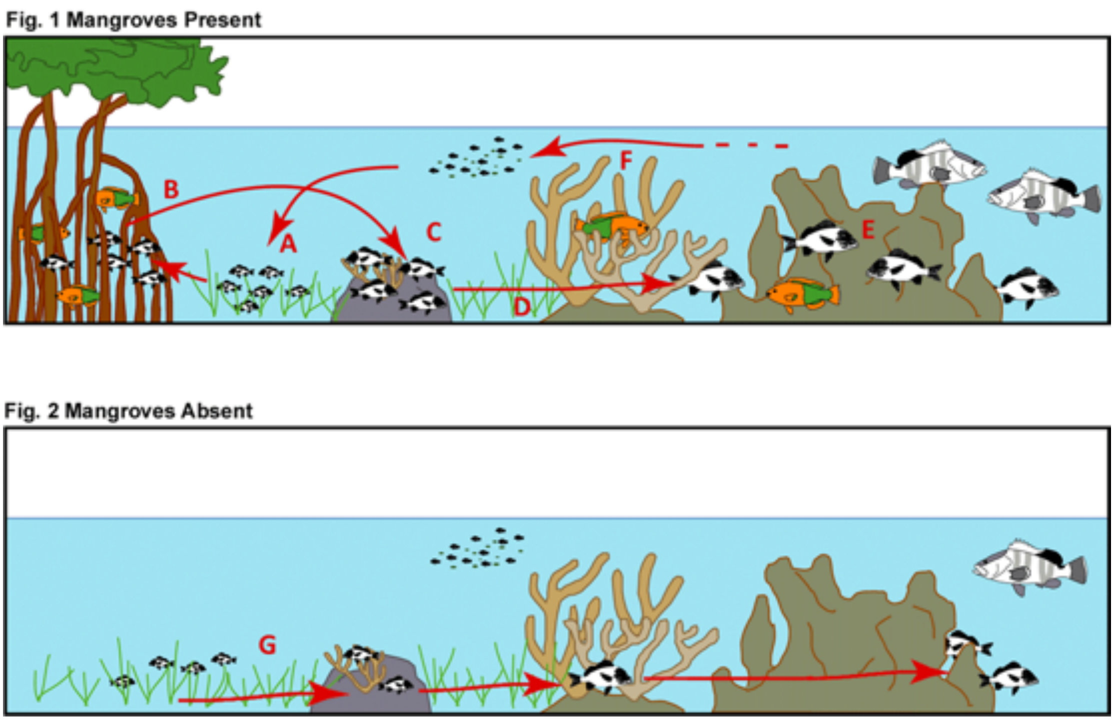


Figure 35. Modified from Mumby et al, 2004. The figures illustrate how connectivity between seagrass meadows, mangroves, and coral reefs can affect the size and density of fish (e.g., grunts and parrotfish). Top - Mangroves Present: Red letter "A" shows juvenile grunts, once reaching a given size in a seagrass meadow, moving to mangroves (B). The mangroves serve as

an intermediate nursery habitat before the fish migrate to patch reefs (C), and fish biomass is significantly enhanced on patch reefs (C), shallow forereefs (D), and Montastrea reefs (E). Some fish (F), such as certain species of parrotfish, Scarus guacamaia, are dependent on mangroves and are not seen where mangroves are absent. Bottom - Mangroves Absent: If the mangroves are not present, then fish move directly from the seagrass to the patch reefs, appearing on patch reefs (G) at a smaller size and at lower density, thus more vulnerable to predation.

Papers detailing habitat association and connectivity often consider two key measurements; the relative faunal diversity by habitat, and the relative faunal density of individual species by habitat. Where possible the maturity of those species, often measured by Total Length (TL) relative to Length at Maturity (Lm), is also calculated (e.g. Nagelkerken and van der Velde, 2002; Unsworth et al., 2008) so that inference can be made as to each habitat's role in the life-history of a species in question (e.g. nursery role, foraging habitat etc).

Food Web Interactions

Understanding the context of extraction is key to understanding fisheries sustainability. For example, in marine systems, changes in herbivory and the consequent loss of dominant habitat forming species (i.e. seagrass) can result in dramatic species assemblage 'phase shifts', such as from coral to algae or from seagrass to un-vegetated sandy substrates (Eklöf et al, 2008; Vergés et al, 2014).

Marine communities are thought to be more strongly regulated by top-down forces (consumers) than terrestrial communities (Shurin, 2006). Therefore, with this information, decisions can be made as to whether a particular habitat is appropriate for fishing, and if so, for the appropriate gear management allowed for extracting species from the habitat e.g. a speargun is more selective, but has a tendency to target large individuals, or a trammel net, which is less size selective but may capture undersized individuals.

Size-structured predator–prey interactions can be altered by the history of exploitation if that exploitation is itself size-selective (Pauly et al, 1995; Hamilton et al, 2007). For example, selective harvesting of larger predators such as Barracudas can release prey populations such as Salema (Figure 60). This can be marked in cases where only large predatory individuals are capable of consuming a particular prey species (Hamilton and Caselle, 2015).

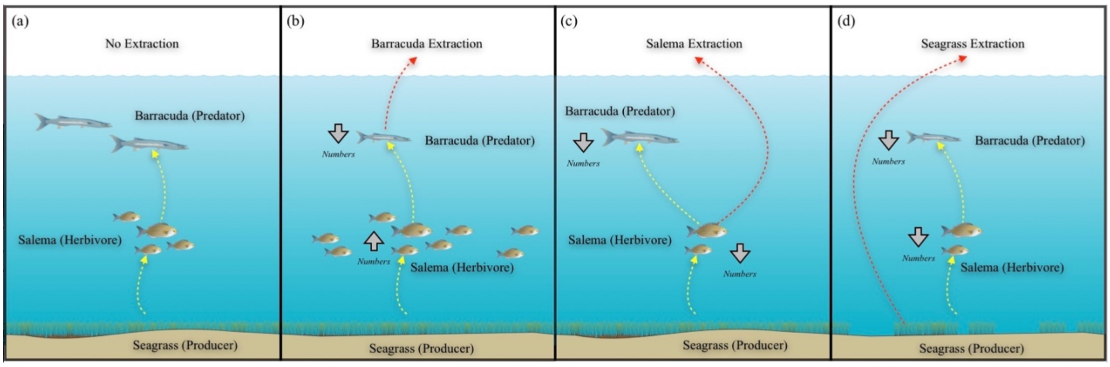


Figure 36. A conceptual model of a hypothetical seagrass food-web. Removal of top-predators (e.g. Grouper and Barracuda) can release prey populations (e.g. Dusky spinefoot, Salema) and trigger overgrazing.

In such cases, there are implications for habitat resilience, because fish and urchins can overgraze kelp (Hamilton and Caselle, 2015), seagrass (Eklöf et al, 2008) or coral reefs (Levitan et al., 1988) in the absence of top-down control. Such food web interactions could potentially reduce both a habitat's *'size and distribution'* and it's *'health'*, reducing its capacity for fisheries provision.

4.6.3 Habitat to Consumer Supply Chain Stage 3 – Fishery

Q3 = Fishery Questions

Q3a – Where is the fishery operating (spatial)?
Q3b – How is the fishery operating (gears)?
Q3c – When is the fishery operating (temporal)?
Q4d – What species is the fishery extracting?

The tertiary stage of the Habitat to Consumer supply chain is the '*Fishery'* which represents the connecting stage of the coupled socio-ecological system. The socio-economic drivers of Stage 4 will affect Stages 1 and 2, and the feedback from Stages 1 & 2 will affect Stage 4. These feedback loops occur via Stage 3. In this context, the 'fishery' refers to the methods through which target species are extracted from a given habitat and in what quantities. Data pertaining to the type and quantity of fishing gear used, and the repetition of gear deployment helps to generate an understanding of 'fishing pressure'. How this is done, is place-based and habitat specific, and subsequently consideration of its 'environmental impact' is important. For example, with fishing pressure and environmental impact, data managers are able to compare the extractive capacity of a small-scale coastal boat to that of a demersal trawler. Evidence relating to the impact of such extractive methods on 1) the benthic habitat, and 2) the associated assemblage can then be generated and the most appropriate gear choice selected for future extraction.

Landings and bycatch

Landings and bycatch are used to calculate the fishing pressure, and the success of the fishery at extracting fish from the environment. Fish landings are defined as the catches of marine fish that are landed at port (OECD, 2016). By-catch refers to the discarded catch of any living marine resource, plus unobserved mortality due to a direct encounter with fishing gear (NOAA, 2016). This data provides information on the extractive rates of the fishery, particularly the abundance of individuals caught by various fishing gears and the age/size at which they were caught. This is important for supply chain sustainability since fish caught prior to reaching length at maturity are unlikely to have spawned and therefore contributed to future stocks (Figure 61).

Figure 37. The practice of returning undersized individuals helps to ensure that juvenile fish have the opportunity to reproduce and therefore contribute to future seafood supply.

Environmental Impact

Environmental Impact refers to the impact of gear choice (type of gear), and application (how it's used), on the ecosystem (habitat and assemblage) being fished. Different gears will impact the habitat and the assemblage in different ways. For example, a 100m x 10m gill net will have very little environmental impact on a seagrass meadow, but a small mesh size would have very different environmental impacts on the assemblage to a larger mesh size. In contrast cyanide fishing (Mous et al, 2000) bleach fishing (Pers. Obvs.) or dynamite fishing (Guard et al, 1997) has a substantial effect on coral reef habitats and thus the assemblages they support, as does the creation of fixed 'fish fences' (Figure 62).

Figure 38. The Indonesian practice of removing coral reefs to establish fish fences causes a permanent reduction in habitat extent. (Photo © Benjamin Jones)

Gears that minimize impact on the habitat and the assemblage should be those that are favoured to achieve SSCM. This can also be achieved through adapting fishing gears to reduce their environmental impact e.g. a turtle excluder device (TED) allows sea turtles and to escape from shrimp trawls (assemblage), or using twin-rig trawls instead of traditional otter boards to reduce seafloor erosion (habitat).

In addition, different seafood species are more or less resilient to overfishing (too much fishing pressure) but this is unique in space and time - different places have different ecological (habitat and assemblage) contexts. To ensure SSCM, requires a place-based understanding of fishing pressure. This knowledge can ensure sustainable extraction of the resource at appropriate spatial scales, and can be garnered by data from catch incidence (including discard) and landings data; where once again both abundance and maturity is considered.

4.6.4 Habitat to Consumer Supply Chain Stage 4 – Market

Q4 = Example Market Questions

Q4a – What is the market infrastructure? (choice-capacity)?
Q4b – What seafood is presented to consumers (choice-task)?
Q4c – How is the seafood presented to consumers (choice options)?

The fourth stage in the 'Habitat to Consumer' supply chain is Market. In the proposed framework, the supply chain stage 'Market' demands an interrogation of the Market infrastructure so as to better understand the influence of the 'choice architecture' (Thaler and Sunstein, 2008) behind the ways products are presented to consumers (Johnson et al., 2012). Not having anything presented will also affect choice since there is no product provision! In this thesis, this concept has been coined 'choice-capacity'.

By investigating the market as a specific supply chain stage develops an understanding of what market infrastructure is available and therefore patterns of seafood provision. Documenting the availability of seafood products e.g. tuna, octopus, prawns (choice-task) and how those products are presented i.e. tinned, frozen, fresh (choice-options) will help contextualise seafood consumption opportunities and its effects on local seafood demand (Scheibehenne et al., 2010, Johnson et al., 2012). For example, an international supermarket may provide the choice of frozen Giant Tiger Prawns (*Penaeus monodon*) to a Greek consumer, which is a product available to a 'modern supply chain' but not available to the consumer from a local SSCF supply chain (Marglas et al., 2015). In contrast, a local fisher only has the capacity to provide a choice of local species (specific to place) that the fisher has the capacity to extract through the local SSCF supply chain.

Infrastructure - Choice capacity

Before the 'choice task' or 'choice options' are even a consideration (see Johnson et al., 2012) for discussion, there is a need to consider 'choice capacity'. As articulated previously, there is no 'global market' for seafood, rather there is a set of globally connected "local" supply chains. Should the products available to those supply chains not reach the 'place' under consideration, then they will have no bearing on either 'choice task' or 'choice options'. In many places, the 'choice capacity' for seafood products is facilitated by supermarket provision (Figure 63) and their extensive retail power in the places in which they operate (Cohen et al., 2013; Maglaras et al., 2015). However, in other places, where there is no supply chain infrastructure, there is no possibility for discussion around what seafood products to offer customers (choice task) because only certain (local) products are available.

Figure 39. A Greek supermarket on Leros. The very presence of a supermarket in a place presents the capacity to access seafood supply chains that were not available to access before. Photo: RJLilley

Availability - Choice task

Tools for structuring the choice task address the idea of what to present to consumers (Johnson et al., 2012). The choice architect (or architects) here is the person (or persons) who decides what products to sell, be they a combination of supermarket buyer and store manager (on a large scale) or a café owner (on a small scale). One of the starkest decisions facing a choice architect is the question of how many alternatives (choice options) to present to the decision maker (Johnson et al., 2012). For example, (if the option is available, 'choice capacity') the choice architect decides if the consumer be presented with one seafood option at time, or two options, or even ten or twenty or more?

There are times past when a consumer may have had too few options, such as when the original Ford Model T was available *'in any colour—as long as it was black'*

(Johnson et al., 2012). Yet more recently, there has been an argument that consumers have had too many options, a situation referred to as the *'tyranny of choice'* (Schwartz 2004) or of *'choice overload'* (Iyengar and Lepper 2000) and this is expressed through the range of competing (and yet very similar) seafood products available to consumers e.g. tins of Short mackerel (*Rastrelliger brachysoma*) Atlantic mackerel (*Scomber scombrus*), Chub mackerel (*Scomber japonicas*) Atlantic chub mackerel (*Scomber colias*) etc.

In interrogating a SSCF supply chain it is important to understand the seafood products available at the 'market' of your 'place' of study (the marketplace!). What are the competing products on the market which provide the consumer with choice? For it is the choice of products presented that will have a direct bearing on the level of demand and consumption of seafood products originating from the Small-Scale Fishery. The global trend in marketplaces is for more, not fewer options to be presented to the consumer (Johnson et al., 2012), and it has been suggested by Underwood (2003) that the proliferation of brands in the market and the varied range that a purchaser finds at the point of sale, forces efforts to achieve effective differentiation.

Understanding 'choice task', even from simply understanding what products are available (Figure 64), can better help shape our understanding of seafood demand/supply, and thus help supply chain managers to direct choice towards sustainable seafood species.

Figure 40. Does the presence of canned mackerel and tuna imported from Thailand alter the 'choice task' for consumers? Does this lower demand for tuna and mackerel from the Small-Scale Capture Fishery?

Presentation - Choice options

Tools for structuring the choice options address the idea of how to present choice since '*the seemingly innocuous feature of a choice environment can have a dramatic impact on choice behaviour*' (Johnson et al., 2012). Studies with consumers have shown that altering the amount of food in a 'single serving', or by simply rebranding a product, altered how much and of what producst were consumed overall (Wansink et al. 2011; Wansink et al. 2012). In addition, it has been found that consumers tend to seek variety when choosing products for future consumption (Read and Loewenstein 1995).

Therefore, by both lowering, and biasing the number of categories of food (a process known as 'partitioning') choice architecture can tap into the 'pervasive tendency toward even allocation' of product choice (Johnson et al., 2012). For example, if a supermarket was to segregate locally sourced food options into separate menu categories (e.g., "seabream", "rabbitfish", "scorpionfish") and integrated imported options into a single menu category (e.g., "imported fish"), one could 'nudge' participants into choosing more local products and fewer imported ones.

This knowledge is particularly powerful given that, people make an average of 200 to 300 food consumption decisions in any given day (Wansink and Sobal 2007), and to reduce the cognitive requirements of so many decisions, individuals may rely on heuristics or decision-rules to guide consumption decisions (Wansink et al., 2009; Wansink 2010): Such habituation means than consumer decisions can become rigid and unresponsive to change, even in the face of novel information pertaining to health, nutrition or sustainability (Johnson et al., 2012) or to traditional marketing tools that shape a product's position in the marketplace.

Whilst the relationship between product positioning and the marketing mix (pricing policy, place, products and promotion) is complicated – it is often thought that the marketing mix is what drives the products position in the marketplace (Figure 65).

Figure 41. The presentation of the seafood product is known to have a dramatic impact on consumer choice.

However, the ‘positioning’ of a product in consumers’ minds (Ampuero and Vila, 2006) will influence its desirability and will in turn reflect the ‘marketing mix’ for the product (Brooksbank, 1994; Bigné et al. 2000). Product positioning has been described as ‘*a subjective and relative concept’* because it is defined in the minds of consumers taking into consideration the rest of the products the marketplace offers (Ampuero and Vila, 2006).

4.6.5 Habitat to Consumer Supply Chain Stage 4 – Consumer

Q5 = Example Consumer Questions

Q5a – What is the local demand for seafood?
Q5b – What is the tourist demand for seafood?
Q5c – What is the cost of seafood?

The final stage of the Habitat to Consumer supply chain is the '*Consumer'*. Consumer refers to the end user, the final purchaser of the seafood product. In reality, the post-harvest (post-fishery) supply chain could be subdivided into several stages or sub-stages to suit individual place-based examples, with place appropriate supply chain stages. However, there will always be an end-user or final consumer that is driving the product demand.

Social structure is defined as a system of geographically dispersed rules and practices that influence the actions and outcomes of large numbers of social actors (UNEP). The importance of capture fisheries in coastal communities as a source of food and economic activity makes it a major determinant of social structure. In human communities, drivers of change to socio-economics include, but are not limited to (after Perry et al, 2010):

i. Resource changes
ii. Environmental changes
iii. Demographic changes
iv. Economic changes
v. Technological changes
vi. Law changes
vii. Governance and policy changes
viii. Value changes

At any spatial scale, the socio-economic context is essential in identifying drivers of extraction; yet in many traditional ecological studies scant regard is paid to the consumption patterns of the social system that drives extraction from the ecological system. It is noteworthy that in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995) that socio-economic drivers are considered, particularly when striving to promote responsible fishing practices.

Social drivers

It is clear from the socio-ecological literatures that different factors drive marine resource extraction at different social-political levels (Kronen et al. 2010). Economic exclusion, social marginalization, class exploitation and political disempowerment have all been identified as factors in resource degradation (Béné, 2003; Béné et al, 2011; Nayak et al., 2014). In addition to these drivers, transdisciplinary outreach to literatures surrounding tourist and hospitality management highlight the extent that seasonality can have on both local and distant resource extraction (Figure 66), in particular how 'tourist' demands for particular foods may well differ from 'local' demands (Chang et al., 2010, Mak et al., 2012).

Figure 42. Is deli salmon (*Salmo salar*) provided by supermarkets on Patmos because of consumer demand? At €51.90/kg what is dictating demand for this imported marine product?

The factors influencing tourist food consumption and 'food choice' (Mak et al., 2012) have been framed pertaining to their 'essentiality' on one hand (Richards, 2002), in line with the conventional ideas of 'food security', and yet also regarding its symbolic nature on the other (Chang et al., 2010; Kivela & Crotts, 2006).

Food choice has been defined as '*a set of conscious and unconscious decisions made by a person at the point of purchase, at the point of consumption or any point in between'* (Herne, 1995) and in its aggregate form 'food choice' creates the consumer demand for suppliers in the food system who produce, process, and distribute food (Sobal, Khan, & Bisogni, 1998). However, 'food choice' also plays an essential role in the symbolic, economic, and social aspects of life as it is a way to express preferences, identities, and cultural meanings (Sobal et al., 2006).

Inclusion of socio-economic research in the supply chain is essential since local people, within a system of interest (e.g. fishers in a fishery) are likely to have knowledge that is not available to system observers (e.g. scientists). Outreach to this knowledge (Figure 67) can aid in understanding social processes that lead to resource decline (e.g. Berkes et al., 2000).

Figure 43. Outreach to local knowledge systems (e.g. fishers in a fishery) are important mediums for understanding the social drivers of resource overexploitation.

Local perceptions are also likely to support accurate and representative quantitative models, and therefore add weight to the evidence gathered. If they conflict with quantitative models, they can also force the review of conclusions drawn from quantitative study. Critically, the understanding of local perceptions is also likely to aid in developing a realistic supply chain management agenda because, if local perceptions are not aligned with scientific conclusions, then the application of management initiatives (SSCM) will likely be untenable (Foale 2006).

Economic drivers

A well-managed small-scale fishery can have greater sustainability, lower environmental impacts and greater equality of wealth distribution than larger-scale and industrial fishing enterprises (Pauly et al., 2002). However, where a small-scale fishery is connected to strong market demand, or in the absence of management (or management enforcement) similar drivers that push industrial fisheries to overexploit resources in international waters exist (Box and Canty, 2010). With no effective management or enforcement to restrict activities the short-term rewards outweigh long term sustainability because of open access (Garcia and Rosenberg 2010). Here, the tragedy of the commons (Gordon 1954; Hardin 1968) push fishers into partaking in a "race to fish" with each fisher attempting to catch as many desirable fish as economically feasible.

Allowing market forces alone to operate on small-scale fisheries without regulation will not promote sustainability, since an axiom of profit maximization is to drive down the buying price whilst increasing the sale price. Under such a free market system those species with the greatest threat of overfishing will be those in greatest demand, providing a predictable pattern of exploitation known as “Fishing down the food web” (Pauly et al, 1998; Pauly et al 2005) Fishers, having depleted the large predatory fish on top of the food web, turn to increasingly smaller species, finally ending up with previously spurned small fish and invertebrates.

4.7 Discussion - The 'Habitat to Consumer' Conceptual Framework

Transitioning to supply chain sustainability is not only an ecological problem of collapsed stocks and degraded habitats, but the process of rehabilitating the entire social-ecological system. This rehabilitation involves managing the connections between resources and people (the supply chain) in the context of shifting socio-economic power dynamics (Nayak and Berkes, 2012; Nayak et al., 2014) and against the backdrop of global ecosystem change (Ostrom, 2010).

However, because seafood supply chains are unique both in time and space, the management initiatives proposed to ensure their sustainability must be informed by, and appropriate to, the place and scale over which the supply chain exists. It is recognised that the role of the consumer is critical in shaping supply chains and that:

"conservation is primarily not about biology, but about people and the choices they make"

Balmford and Cowling, 2006.

Problems have arisen because management strategies have often ignored the socio-economic aspects of small-scale fisheries which provide an important source of food, income and livelihoods for fishing communities (Dugan et al., 2006). However, the absence of robust and trustworthy information on fish catches inhibits efficient management, thereby reducing the likelihood of SSCM and protection of fishers' livelihoods. Traditional knowledge within fishing communities could fill this gap and improve conservation of fisheries resources and their management (Berkes et al., 2000) and thus outreach to traditional and local knowledge any place-based SSF SSCM framework.

Whilst these elements are increasingly investigated within coupled socio-ecological systems literature, there has to date been no formalised incorporation of both the demand-side and supply-side drivers of small-scale fisheries supply chains. Demand-side variability can be influenced as much by social traditions as passing fashions, or by marketplace competition linked to resource availability (Cullen-Unsworth et al, 2014; Unsworth et al, 2014; Horner and Swarbrooke, 2016); whilst supply side variability is very much rooted in the structural ecology of the coastal habitats, and their effective management.

Collectively, the propositions proposed in this chapter provide a new conceptual framework for Ecologically Dominant (ED) Sustainable Supply Chain Management (SSCM) for Small-Scale Capture Fisheries (SSCF). The framework presents a 'holistic' product life-cycle for seafood, that combines the "below the surface" ecological elements usually considered by ecologists and environmental economists, with the "above the surface" *catch to market* elements that traditional economists, supply chain management scholars and other management theorists would consider.

There are three novel elements to the framework;

1. The adoption of an **'Ecologically Dominant'** logic that can lead to the development of sustainable supply chain management; and rejection of the Economically Dominant logic which cannot.

2. Product life-cycle, **'Habitat to Consumer'** thinking ensures that each of the five stages (Habitat, Assemblage, Fishery, Market and Consumer) in a small-scale capture fishery supply chain is considered; in particular, the pre-catch stages of 'Habitat' and 'Assemblage' that are overlooked by the FAOs '*Catch to Market'* thinking which treats the sea as a homogenous entity.

3. A **'Place-Based'** approach to both sustainable supply chain research and management, that ensures that any management decisions are informed by, and appropriate to the place under consideration.

The adoption of these three proposals will help to promote the sustainability of the marine ecological systems (Habitat and Assemblage) upon which the small scale capture fisheries (Fishery) are their associated socio-economic systems (Market and Consumer) depend.

1. Ecologically Dominant

An Economically Dominant logic results in Supply Chain Management (SCM) decisions based upon the standpoint "Is this management decision good for profits?" Such an 'inside-out' logic limits management to focus on unattainable 'win-win' initiatives over short time horizons (Montaban et al., 2016). This results in SCM decisions merely making the supply chain 'less unsustainable' but cannot lead to sustainability because the trade-offs are never fully addressed. In contrast, the novel Ecologically Dominant adopts an 'outside-in' logic which forces the supply chain managers to focus on doing no harm and assess their economic activity both on environment and on society (Table 9).

Under such an Ecologically Dominant logic, *Sustainable* Supply Chain Management (SSCM, as opposed to SCM) would focus on 'harm elimination' instead of 'profit maximisation' and thus make decisions over much longer time horizons (Montabon et al., 2016). In order to survive economically a supply chain functioning under this logic would have to significantly alter both what they do and how they do it, and accept that by taking social and ecological responsibility, they may not satisfy certain consumer demands (Montaban et al., 2016).

Table 10. Small-Scale Capture Fishery Stakeholder Roles under Economically Dominant and Ecologically Dominant Logics (adapted from Montaban et al., 2016)

	Economically Dominant: The small-scale fishery is in the centre of a stakeholder network where stakeholders are either enablers or inhibitors of the fisheries primary goal of profit maximisation	**Ecologically Dominant**: The ecological system in the centre of a stakeholder network where stakeholders are either enablers or inhibitors of the ecosystem's primary goal of sustaining life.
External to the Supply Chain		
Communities where the chain operates: Ecological system	**Role**: Source of seafood (natural resource) **Question**: How to provide an uninterrupted flow of seafood to satisfy customer demand while minimizing pollution and maximizing resource efficiency?	**Role:** Central **Question:** How to maximise the supply chain's productivity while doing no harm to the environment's ability to sustain life?
Communities where the chain operates: Social systems	**Role:** Mostly absent, except for place to do business **Questions:** Where to locate to maximize supply chain economic performance while minimizing costs of labor, regulatory compliance, and disruptions?	**Role:** Central **Question:** How to maximize supply chain value while at a minimum doing no harm to quality of life?
Within the Supply Chain		
The focal firm	**Role**: Central, profit maximisation **Question**: How can the small-scale fishery in a small-scale fishery supply chain benefit from addressing environmental or social issues? Does it "*pay to be green*"?	**Role**: Co-ordinator of chain **Question**: How to provide the supply chain's value in a sustainable manner?
Suppliers	**Role**: Source of risk or negative impacts to be managed to protect firm profits **Question**: How can habitat management, fishing codes of conduct and gears of extraction deployed etc insure that habitat provision meets the small-scale fishery's expectations?	**Role**: Potential source of harm and opportunity, especially when managing a habitat for multiple stakeholders (not just supply chain provision) **Questions**: How to insure supplier continuity? How to build fishery supply chain without first doing ecological or social harm?
Consumers	**Role**: Excuse for '*organised irresponsibility*'; source of demands otherwise mostly absent **Question:** How to maximise profits by meeting or exceeding all expectations, including environmental and social expectations?	**Role:** Source of demand **Question:** how to provide the supply chain's value in a sustainable manner?

2. Habitat to Consumer

To ensure the sustainability of coastal small-scale fishery supply chains, the design and implementation of a full (i.e. entire life cycle) backward and forward traceable seafood supply chain, from '*Habitat to Consumer'* must become an important part of both the quality assurance and coastal resource management system. A compendium of all definitions for food product traceability was proposed by Olsen and Borit (2013):

"The ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications".

Supply chain visibility is being pushed to 'a new stage' by government regulations and consumer requirements (Badia-Melis et al 2015) meaning that food traceability is becoming *'a reality that will go from farm* [or habitat] *to fork'* (Min Aung & Seok Chang, 2014). This framework argues that for the longevity of any resource management scheme, we need to move beyond the FAOs 'catch to market' thinking by extending our conceptualisation of the system to the supply chain pre-catch, and thus defining the seafood supply chain from "Habitat to Consumer"

3. Place-based.

The management of the supply chain will be inherently linked to place, since coastal habitat distributions are both place-based and heterogeneous. Whilst there may be overlap between the management requirements of a Caribbean Sea coral reef fishery, a Baltic Sea temperate reef fishery and a Mediterranean Sea seagrass fishery, the challenges of managing the seafood supply chains in each of these regions will be as unique as the coupled socio-ecological systems they support. The suite of fisheries management control perspectives outlined in this chapter are transferable across regions and places, and yet the appropriate combination of measures will require both local ecosystem knowledge and local socio-economic system knowledge for them to be effective.

What is key to the successful implementation of SSCM initiatives is to identify both the socio-economic indicators and drivers that will improve our understanding of the coupled socio-ecological system dynamics. In particular, between the socio-economic conditions and the rate and methods of exploitation of marine resources e.g. Kronen et al, 2010). Critically however, it is then also about how to use this knowledge to ensure the sustainability of a supply, which is firmly rooted in biological integrity of the ecological system.

The key message is that it is only through a *complete interrogation* of the *entire seafood supply chain* (something which is inherently unique to place), and through exploring both the demand side, and supply side drivers of the supply chain, that a holistic understanding of small-scale fishery supply chains will be achieved.

CHAPTER 5 – Supply Chain Stage 1 - Habitat

5.1 Introduction

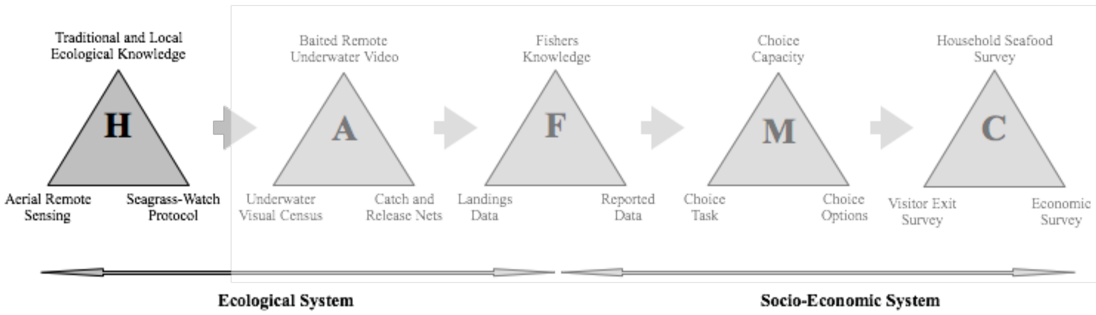


Figure 44. This chapter focuses on the Habitat (H) as the supplier of seafood products to the Small-Scale Capture Fishery supply chain. This supply chain stage is located within what would be conventionally conceptualised as the ecological system within the combined socio-ecological system.

For traditional supply chain scholars, SCM is classically based around the principles of *inter-organisation* relationships. Under this conventional scenario, it can generally be assumed that supplier behaviour will depend upon both the established power relationships, and the downstream behaviours of actors within the supply chain. For example, if end consumers were not to pay their bills on time, this could impact on a traditional organisation/industry to obtain product supply, with a lack of available capital/cash preventing the purchasing of products from the suppliers.

However, in the case of a marine fishery, product supply is not negatively affected by lack of demand on the part of the consumer, with the coastal habitats provisioning seafood regardless. Therefore, in this conceptualised SSCF scenario, the supply chain risk for Habitats (i.e. seafood quality or quantity problems) does not come from lack of payment by end users, but rather comes from actions by the stakeholders in the supply chain itself (e.g. the behaviour of fishermen), or from other competing activities that share the same physical space, but not the same ecosystem services (e.g. recreational boat users). In this example, there could thus be multiple feedbacks that derive from the 'social' sphere that can directly impact product supply, for example overfishing or habitat destruction.

In turn therefore, for the SSCM of SSCF supply chain, management initiatives are likely to be different to those articulated for more ‘conventional’ supply chains. For example, in the marine fishery, the ‘behaviour’ of the ecosystem (habitat and assemblage) can be highly variable in space (fish movement) and time (weather, season), creating an unpredictability of supply that is unconventional in traditional supply chain conceptualisations. For this reason, it is also with the supplier that some ‘power’ sits in this supply chain, since, there is limited amount of control over the variables that influence product supply.

In many respects, conventional ‘farm-to-fork’ agriculture or aquaculture supply chains are attempts to limit this supply-side variability (to behave more like traditional supply chains), but they too can have high dependency on these extraneous variables. Critically though, under explicitly place-based systems (i.e. a field, or a sea pen), it is at least possible to influence the supplier (farmer) in terms of what to grow, and when. Under broader place-based systems, such as this coastal ‘capture’ fishery, ‘protected area’ management initiatives are more limited towards protecting the coastal habitats (suppliers) upon which the seafood supply depends. These are then often complemented by quota / size / gear limitations which aim to manage the product supply, but not necessarily the ‘capacity’ for product provision.

Under a SSCF SSCM scenario, the habitat and assemblage, which act as the first two links in the supply chain are reliant on a relationship that can’t be totally controlled but relies, in a large part, on good fisheries management. In a place-based setting like the Lipsi SSCF, successful SSCM therefore depends on getting accurate information about the habitats (as seafood suppliers), particularly relating to their *Size, Distribution* and *Health*.

The Coastal Zone

The coastal zone includes areas of continental shelves, islands, estuaries, lagoons, beaches and terrestrial and aquatic ecosystems with watersheds that drain into coastal waters (Wang, 2010). This dynamic interface between land and sea is where nearly 40% of the world’s population lives (Ferrario et al, 2014). Therefore, the anthropogenic effects on coastal habitats need both quantifying and monitoring, so that this data can inform their effective management, and thus the sustainability of ecosystem services they provide. SSCM for the *Habitat to Consumer* supply chain begins with defining the habitats under consideration to determine priorities for spatial management and habitat protection (Giakoumi et al., 2011).

Over the past few decades, there has been an increasing interest in tools for environmental monitoring, developed with a variety of purposes, including the conservation of fish habitats. These tools have application at multiple spatial scales; from the patch (e.g. MacKenzie et al., 2003) to the site (e.g Ventura et al., 2016), to the local (Sagawa and Komatsu, 2015) and the regional (Teixeira et al., 2013). Utilising the appropriate tool for the appropriate scale is often the challenge in social-ecological systems research, and yet triangulation of data across scales and disciplines can lead to a more holistic understanding of coastal processes.

Ecosystem Based Fisheries Management

The affinity of individual species or species assemblages to habitats (and thus geographic locals) is central to the EBFM concept (Pikitch et al., 2004); certain habitats supply certain species to a particular seafood supply chain. Ergo, from a SSCF supply chain perspective, effective EBFM sustains the essential product supply derived from a given habitat type within a given coastal zone habitat mosaic. Combining these concepts in pursuit of SSCM in marine fisheries is a key development, and a unique approach to the challenge of SSCM, especially since scholars in this field often ignore the availability (or supply) of natural resources as a supply chain risk factor (Matopoulos et al. (2015).

At present, the spatial distribution of many marine species is unclear, making it essential to improve our understanding of fish-habitat associations to support sustainable EBFM (Guidetti, 2000; Sheaves and Johnson, 2008; Moore et al., 2009). An understanding of both the relative sizes and geographic distributions of coastal habitats is therefore crucial to tackle the spatial patterning of species communities and their correlation with fisheries catch (Mumby and Edwards, 2002; Manson et al., 2005).

Characterising Habitats

Quantitative Approach: Aerial or Satellite Remote Sensing and subsequent 'supervised' or 'unsupervised' delineation of marine habitats (through orthomosaic creation and photo-interpretation) is a developing field, used by ecologists and other coastal researchers, since it enables scientists to map and assess fragile marine environments without disturbing them (McEvoy et al., 2016). Recent advances in remote sensing technologies, coupled with price decreases, are improving the power and availability of small-scale (e.g. Unmanned Aerial Vehicles [UAVs]) remote sensing tools (Bryson et al, 2013; Barrell and Grant, 2015).

Qualitative Approach: SSCM of natural resource supply is challenging when many of the world's most vulnerable and rapidly changing ecosystems are amongst the most data-poor (Beaudreau and Levin, 2014). This concern, along with pressures for cost saving, has promoted the use of place-based knowledge systems in establishing habitat and species distributions, resource use and stakeholder activities (Wilder et al., 2016), to understand both long-term, and short-term environmental changes (Huntington et al, 2004; Moller et al, 2004). For this reason (or similar) quantitative habitat assessment is increasingly combined with more qualitative approaches, including the incorporation/use of Traditional and Local Ecological Knowledge (TLEK).

Ethno-ecological knowledge derived from interviews with resource users has been combined with more traditional scientific ecological knowledge (SEK) to facilitate modelling of past systems (Pitcher 2001) and document spatial distribution of habitats across coastal zones (Teixeira et al., 2013). The integration of social and natural science methodologies has gained traction over the past decade, with a recognition that TLEK and SEK approaches can be complementary and provide increased confidence in conclusions drawn (Huntington et al, 2004; Thornton and Scheer, 2012), and offer solutions to research challenges across multiple spatial scales (Figure 69)

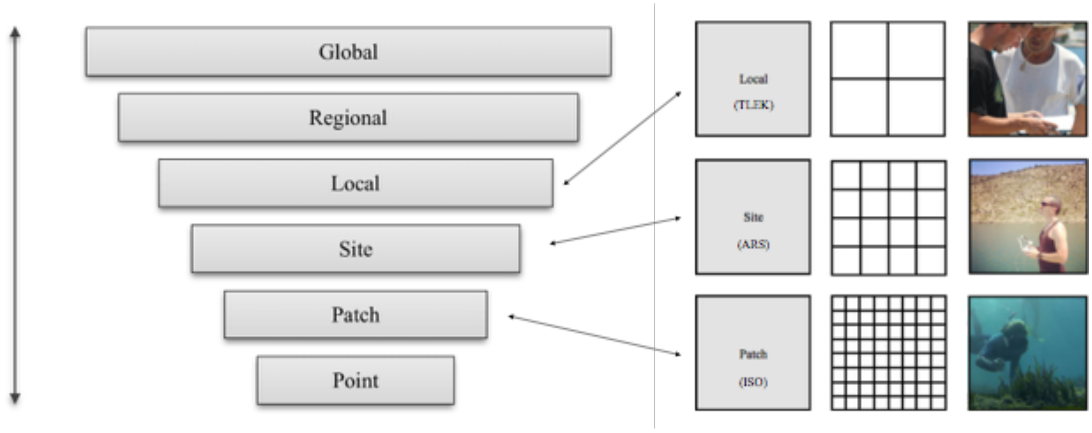


Figure 45. Utilising a multi-method approach enables 'scale-appropriate' research methods to be pursued in order to answer research questions that exist across multiple spatial scales. In this scenario TLEK = Traditional and Local Ecological Knowledge. ARS = Aerial Remote Sensing and ISO = In-Situ Observations.

Methods Section

In this place-based study a multi-method approach is adopted, integrating small-scale Aerial Remote Sensing (ARS), In-Situ Observations (ISO) and Fishers Traditional and Local Ecological knowledge (TLEK). Understanding habitat distribution is needed to manage coastal resources, and this need is addressed across the coastal zone of Lipsi at multiple spatial scales. No measurement technique meets all research needs. However, combining ARS, ISO and TLEK, this chapter demonstrates a multidisciplinary approach undertaken to achieve a richer picture of coastal zone habitats (Figure 69). Fishers' TLEK is useful for mapping the broad boundaries of habitats, whereas accepted scientific approaches allow for a more detailed understanding of distribution, size, health of habitats within those boundaries.

5.2 Aims and Objectives

This chapter focuses on establishing data pertaining to the habitat as the seafood 'supplier'. This chapter focusses on the following elements:

1. What are the local habitats present in the Lipsi coastal zone? (*define the seafood suppliers*)
2. What is the spatial distribution of these habitats within the coastal zone? (*size and distribution*)
3. What are the characteristics of these habitats? *(health)*

Objectives

1. To utilise Traditional and Local Ecological Knowledge (TLEK) to create a typology of habitats present in the Lipsi coastal zone.
2. To establish spatial distribution of habitats drawing on Traditional and Local Ecological Knowledge (TLEK).
3. To trial photographic mapping of chosen sites via aerial remote sensing (ARS) using an Unmanned Aerial Vehicle.
4. To trial quantification of habitat type and extent from orthomosaic creation.
5. To generate quantitative data of habitat characteristics through in-situ observation (ISO), to ground truth and contextualize habitat data generated by remote sensing techniques.

5.3 Materials and Methods

"To assist with choosing a mapping strategy, it is a good idea to conduct a reconnaissance survey"

McKenzie et al, 2003.

An initial 'reconnaissance survey' of Lipsi was conducted from November 21st – December 21st, 2014, enabling the selection of appropriate methods for capturing both the distribution of habitats, and for planning subsequent data collection activities. The simple pre-mapping of habitats enabled the sourcing of the most scale-appropriate and logistically / financially viable materials and methods for habitat mapping.

In this chapter, Traditional and Local Ecological Knowledge (TLEK) was used to create a typology of habitats present in the Lipsi coastal zone. This work provided a basic map of local habitat distribution and acted as a medium for generating local habitat typology. Concurrently, sites were selected for the deployment of a small-scale aerial remote sensing (ARS) platform and for the in-situ observation, "Seagrass-Watch" methodologies (ISO). This allowed for both the robust quantifying of habitat distribution at the site scale, but also informed extrapolation of data to the local scale. ISOs provided data on intrinsic habitat characteristics (relating to seasonal and site differences). Understanding these patterns across spatial scales is required for appropriate SSCM decisions (Figure 70). This combination of aerial photography and ground-based observations is deemed an effective means of assessing habitat composition and distribution (Shuman and Ambrose, 2003) and has been used in support of a variety of habitat assessments (e.g. Coops et al, 2012; GFOI, 2013).

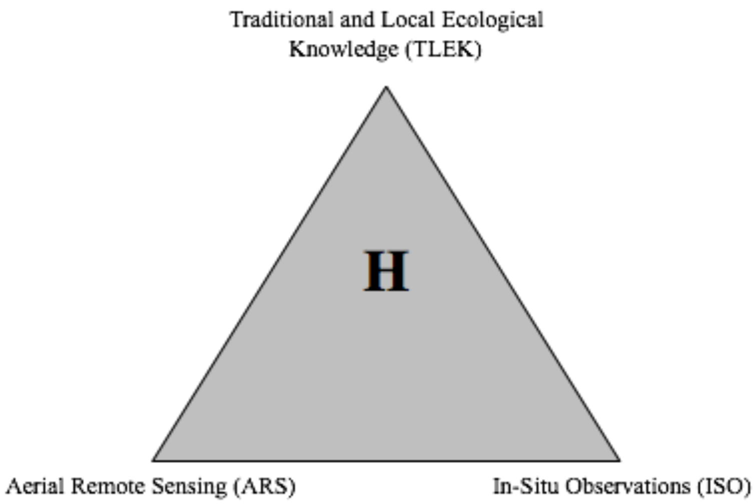


Figure 46.For a richer understanding of habitat, a triangulated approach incorporating Traditional and Local Ecological Knowledge (TLEK), Aerial Remote Sensing (ARS) and In-Situ Observations has been adopted.

5.3.1 Traditional and Local Ecological Knowledge (Local Scale)

Parameters of Study Area

The study region was defined as the Municipality of Lipsi (37°18'N 26°45'E) in the south-eastern Aegean Sea (≈150km^2). Lipsi itself is a 17.35km^2 island, centred within a seascape of ≈132.65km^2 of oligotrophic waters and shallow coastal habitats (Figure 71).

Figure 47. The Municipality of Lipsi (from the north-east), showing the surround islets and the island of Patmos in the distance (to the west).

The climate of Lipsi is semi-arid; with hot (24°C-35°C) dry summers and mild (8°C -15°C) winters (Sauvage, 1963). Coastline geomorphology is heterogeneous and encompasses crystalline or semi-crystalline limestone schists (Bornovas and Rontogianni-Tsiampaou, 1983) which create rocky-algal reefs as they protrude into the sea. The sea depth between Lipsi, and Arki (to the north), Leros (to the South) and Turkey (to the east) does not exceed 100m (Dermitzakis, 1990) and is characterised by areas of shelf, with largely smooth and flat substrate suitable for bottom trawl fishing (FAO, 2008). A deeper water channel to the west of the Lipsi separates the island from Patmos.

Based on the generally shallow ocean topography it was expected that *Posidonia oceanica* seagrass meadows would be found in the 0-50m depth zone (Pasqualini et al., 1998; Procaccini et al, 2003, Infantes et al., 2009). These meadows are protected under the EU's Habitats Directive, and EC Regulation 1967/2006 bans the use of mobile fishing gear over seagrass beds. However, only 8% of meadows in Greece have been mapped (Telesca et al., 2015). Research suggests that this habitat is essential to SSCF fisheries in the region, with a Mediterranean wide contribution of over €190 million/year to coastal economies (Jackson et al, 2015). In addition, Coralline algae could also be expected to be present in the study region, in the deeper waters to the west of Lipsi. These habitats occur at depths beyond 50m (Laborel, 1987; Georgiadis et al., 2009). However, no published data exists for the presence of these habitats within the municipality.

Fisher Interviews

Fisher Interviews were conducted to elicit a locally defined habitat typology and establish a broad habitat *size* and *distribution* at the local scale. Focus group techniques might be biased toward the opinion of a few outspoken or politically powerful participants (Morgan, 1993), and because these interviews were carried out early in the study (January 2014) it was imperative that they were carried out individually, and in a stepwise process to develop the relationship between the fishers and the researcher (Silver and Campbell, 2005; Teixeira et al., 2013). The process involved three fishers over three stages.

Stage 1:

Access was made possible through the head fishermen who acted as a "key informant" and provided access to two further fishers. All three fishers worked full time, using a variety of small-scale fishing gears to target fish in the local area. Each fisher received a blank map (Figure 72) showing Lipsi (its coastline, and surrounding islets) representing a surface area of approximately ≈150km^2. Local translators explained the map references and tasks to the fishers.

To ensure accuracy of habitat description, fishers were queried on the types of habitats they recognized, the names of places corresponding to those habitats, and the physical characteristics of the habitats. Fishers then drew their 'Traditional and Local Ecological Knowledge (TLEK) maps' of the coastal habitats. Each interview took between 45-60 minutes to complete.

Figure 48. A blank paper map of the Municipality of Lipsi was given to participating fishers. Fishers were then asked to draw the distribution of coastal habitats.

Stage 2:

The maps generated by fishers TLEK were analysed highlighting areas of coincidences and discrepancies. All fishers used the following terms to refer to habitats:

(1) *Αμμος*: Sand
(2) *Ποσειδωνια*: Posidonia;
(3) *Βραχωδης πυθμενας*: Rocky Bottom
(4) *Κοραλλιογενη & Βραχωδης πυθμενας*: Coral & Rocky Bottom (Coralline).

Other terms used included: (5) *Ποσειδωνια και Βραχωδης πυθμενας*: Posidonia and rocky bottom, (6) Patchy Posidonia; *Διασπαρτη Ποσειδωνια* and (7) *Αλγες*: Algae.

On fisher's maps the category descriptions for (5), (6) and (7) overlapped with categories (2) and (3). In addition, due to the limited number of fishers' maps available, it was decided to simplify habitats into those four common categories, and which correspond to the habitat descriptions used in the literature for elsewhere in Greece (Kalogirou et al, 2010) and the wider Mediterranean (Guidetti 2000). Rejection and confirmation of features was thus based on overlapping map features.

Stage 3:
Systematisation of Fishers TLEK of habitats follows the methods of Teixeira et al (2013), the data was processed in GIS using QGIS software with polygon shapefiles. Fishers' findings were subsequently analysed and habitat categories were compressed / filtered by the application of two criteria:

1) features similarly classified on more than one map prevailed over a single or fewer divergent maps.

2) features mapped by senior fishers (more experienced) prevailed over features mapped by more junior fishers (less experienced).

5.3.2 Aerial Remote Sensing (Site Scale)

Study Sites

The nine sites described in Chapter 3: (a) Vroulia, (b) Moschato, (c) Platis Gialos, (d) Kamares, (e) Chochlakoura (f) Limnh, (g) Papadria, (h) Kambos, and (i) Kimissi were chosen for aerial survey by Unmanned Aerial Vehicle (UAV).

These were broadly located around the entire island of Lipsi to be representative of the broader coastal zone (Figure 73).

Figure 49. Lipsi island is located in the northern Dodecanese archipelago, Greece (1:35,000 Scale) showing the location of the town (dark grey) and the nine bays considered in this study (a) Vroulia, (b) Moschato(c) Platis Gialos. (d) Kamares, (e) Chochlakoura, (f) Limnh (g) Papadria (h) Kambos and (i) Kimissi

Site extent was marked by freediving the 9m-depth contour. Ground truthing and scale were provided by a 50m long tape measure captured in the initial photo of a survey run, and by reference to terrestrial focal points e.g. buildings, walls, piers etc.

Data collection

A DJI Phantom 3 Advanced UAV with a built-in Sony EXMOR 1/2.3” camera (effective pixels: 12.4 M) was used to capture habitat *size* and *distribution* data at the site scale (Figure 74).

Figure 50. A DJI Phantom 3 Advanced Unmanned Aerial Vehicle.

Data processing

From the images captured by the DJI Phantom’s visible light camera a photo ‘orthomosaic’ was generated; one complete image that is formulated by the piecing together of multiple images. The images taken during the flights along the transects were transformed into a series of 3D textured models using the image processing software AgiSoft PhotoScan Pro (Figure 75).

NB - For the computation of large projects (with more than 200 photos) a 64-bit operating system with at least 12 GB RAM is recommended (Ventura et al., 2016).

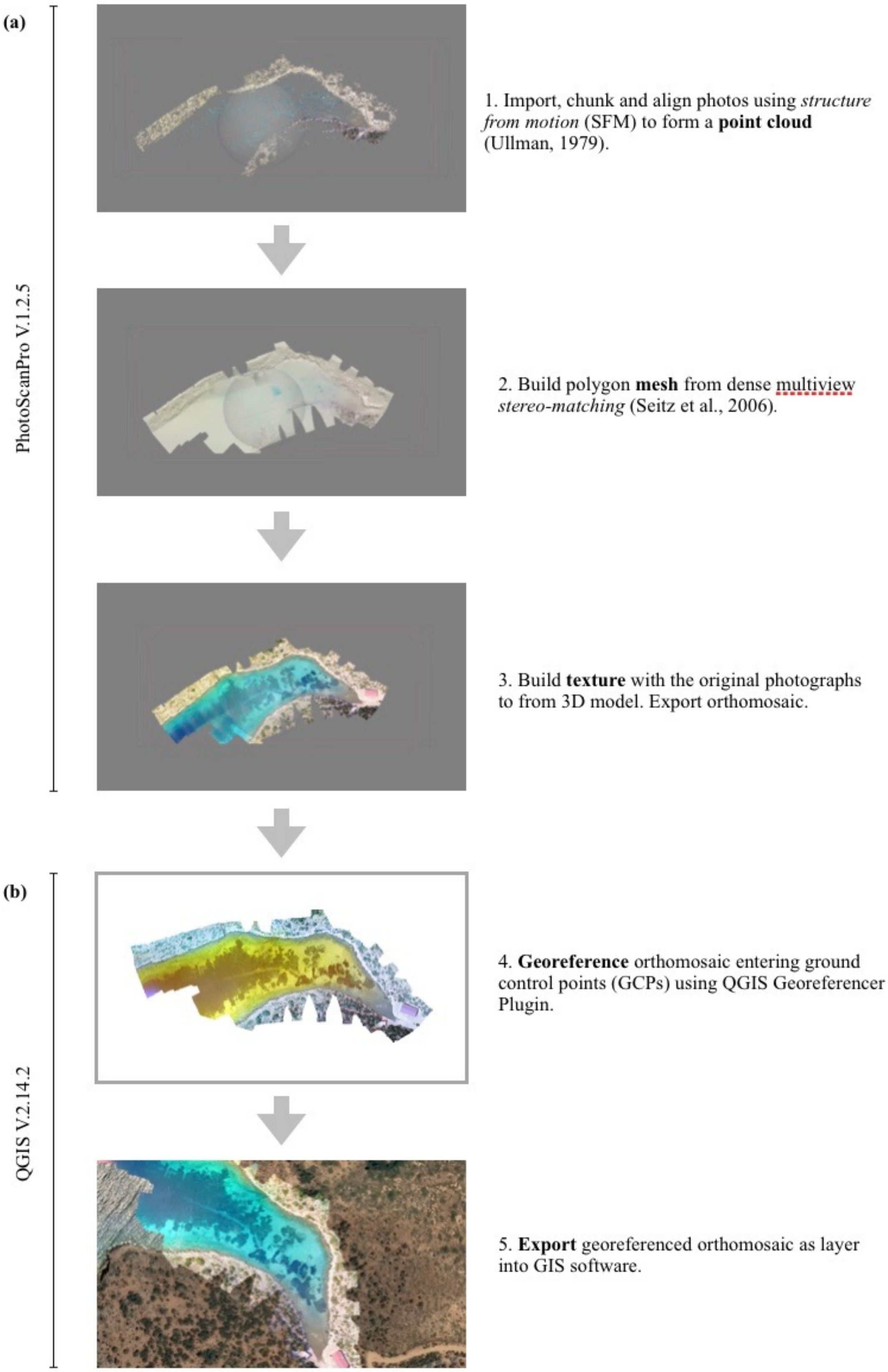


Figure 51. The 5 step of image processing for converting Unmanned Aerial Vehicle aerial photographs into georeferenced orthomosaic layers using PhotoScanPro V.1.2.5 and QGIS V.2.14.2

To calculate actual area coverage of each habitat (m^2) the total pixel coverage for each habitat class was multiplied by the resolution of the image captured (Table 10). This is known as Ground Sampling Distance (GSD).

Table 11. Focal length of DJI camera lens (1/2.3" Sony Exmor) with 35mm Full-Frame for comparison.

Sensor Type	Image Size (mm)	Pixel (Col, Row)	Diagonal Length (mm)	Crop (lens) Factor
35mm Full-Frame	36 x 24	(Various)	43.27	1
1/2.3" Sony Exmor	6.30 x 4.72	4000 x 3000 (12MB)	7.87	5.5

This formula generates the resolution of **2.18 cm/pixel.**

The number of classified habitat pixels (seagrass, rocky-algal, sand) calculated from MultiSpec was then used to estimated site habitat cover. MultiSpec generates quantitative data pertaining to habitat distribution and extent within the orthomosaics by 'classifying' habitats based upon their spectral signals (e.g. seagrass returns a different spectrum of light to the camera than sand does).

5.3.3 In-Situ Observations (Patch Scale)

Study patches

Seagrass *health* characteristics were monitored within 50m x 50m patches within each of the nine sites mapped by UAV (see Figure 73). Seagrass *resilience* characteristics (e.g plant carbohydrate stores / seed banks) were unable to be collected in this study. Four monitoring sessions were conducted seasonally (Winter / Spring / Summer / Autumn) throughout the course of 2014-2015. Habitat characteristics were recorded using the standard Seagrass-Watch rapid assessment technique (McKenzie et al. 2003) to map shallow (<10m) subtidal meadows. All surveyors were trained in the same methodology (seagrasswatch.org/methods). In order to confirm consistency between results, multiple readings of some parameters such as percentage cover were taken to ensure quality assurance (Bunker 2008).

Seagrass-Watch

A ‘Seagrass-Watch’ patch constitutes a 50m x 50m area within a relatively homogenous region (low variability, even topography). At each location, date and time were recorded. Three parallel 50m transects (25m apart) were established using 50m tape measures. The geographic location of the sites was recorded using a Garmin eTrex 10 Global Positioning System (GPS) unit (Figure 76).

Figure 52. A Garmin eTrex 10 GPS unit was used to 'ground truth' study locations.

Water depth was recorded using a Suunto D4 dive watch. Along each transect observers recorded habitat characteristics (including percent seagrass cover, seagrass species composition, sediment type and associated fauna (McKenzie, 2003) with a $0.25m^{-2}$ quadrat (50cm x 50cm) at 5m intervals (11 quadrats per transect, 33 quadrats per site).

Seagrass species within the quadrat were identified and the percent contribution of each species to the total cover was determined (Figure 77). Transects began where *Posidonia oceanica* was first recorded from the shoreline. Canopy height of the dominant *Posidonia oceanica* species was measured (from the sediment to the leaf tip) using a ruler. The method used was to ignore the tallest 20% of leaves and to haphazardly select three leaf blades from the remainder. The cover of epiphytes was recorded by estimating the percent of the total leaf surface area covered by epiphytes. Percent of non-epiphytic algae in each quadrat was estimated using the same visual technique as applied for seagrass cover (McKenzie, 2003).

Figure 53. Freediving (Apnea) allowed Seagrass-Watch methods to be conducted in the shallow-water (<10m) coastal zones around Lipsi.

Field descriptions of sediment type were described using visual estimates of grain size: rocks (200,000µm) rubble (>20,000µm) gravel (>2,000µm), coarse sand (>500µm), sand (>250µm), fine sand (>63µm) and mud (<63µm) and rhizome (for exposed seagrass rhizome). Sediment was then categorized determined by the dominant sediment type (e.g. sand/mud = more sand than mud). The visual/tactile estimation method used in Seagrass-Watch is '*a simple, yet relatively accurate measure of the sediment grain size'* which can be used for quantitative assessments. (McKenzie et al., 2007).

Abundance of any associated fauna within each quadrat was recorded (e.g. molluscs), having been identified to the lowest taxonomic level possible in the field.

5.4 Results

5.4.1 Traditional and Local Ecological Knowledge (Local Scale)

Fishers' Map Interpretation

The ≈150km^2 of seafloor mapped by each fisher is presented in Table 11. There was agreement between fishers for habitat distribution and extent maps for *Posidonia oceanica* seagrass (range: 21.46km^2 to 26.50km^2) and Rocky-algal habitat (range: 19.20km^2 to 25.98km^2). However, there were discrepancies in stated Coralline algal formations extent (range: 5.64km^2 to 17.66km^2) between all three fishers (although the geographic locations identified were similar and overlapping for each). Deep water un-vegetated sandy bottom was only included on the map by Fisher 3, and so correlation is low for sandy bottom habitat (11.55km^2 to 43.27km^2). Unreported habitat type for areas of the seafloor ranged from 25.14km^2 to 74.80km^2, and were confined to areas away from the island (or islet) landmasses (Figure 78).

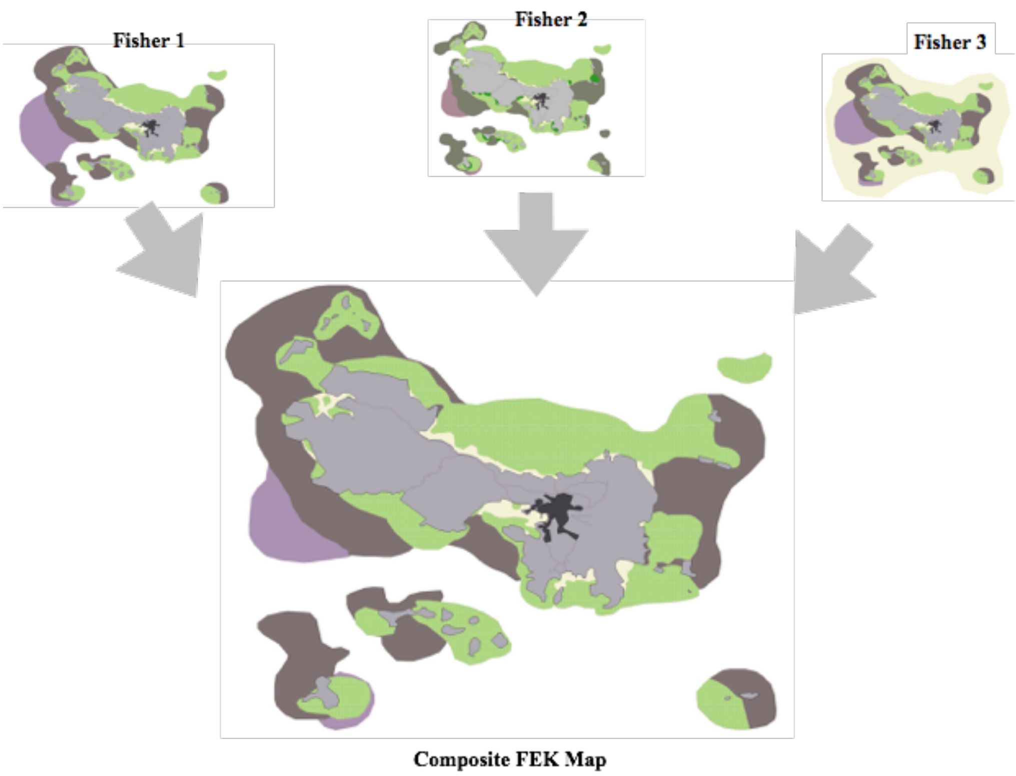


Figure 54. A composite fishers map was achieved through systematisation of habitat FEK from each of the three fishers' maps.

Map correspondence was deemed acceptable for focal habitats, and thus a composite map was created (Figure 79). Benthic habitat classes were subsequently validated on subsequent trips with fishers, and during subsequent coastal breath-hold dives (<30m) around the island (100% habitat correspondence).

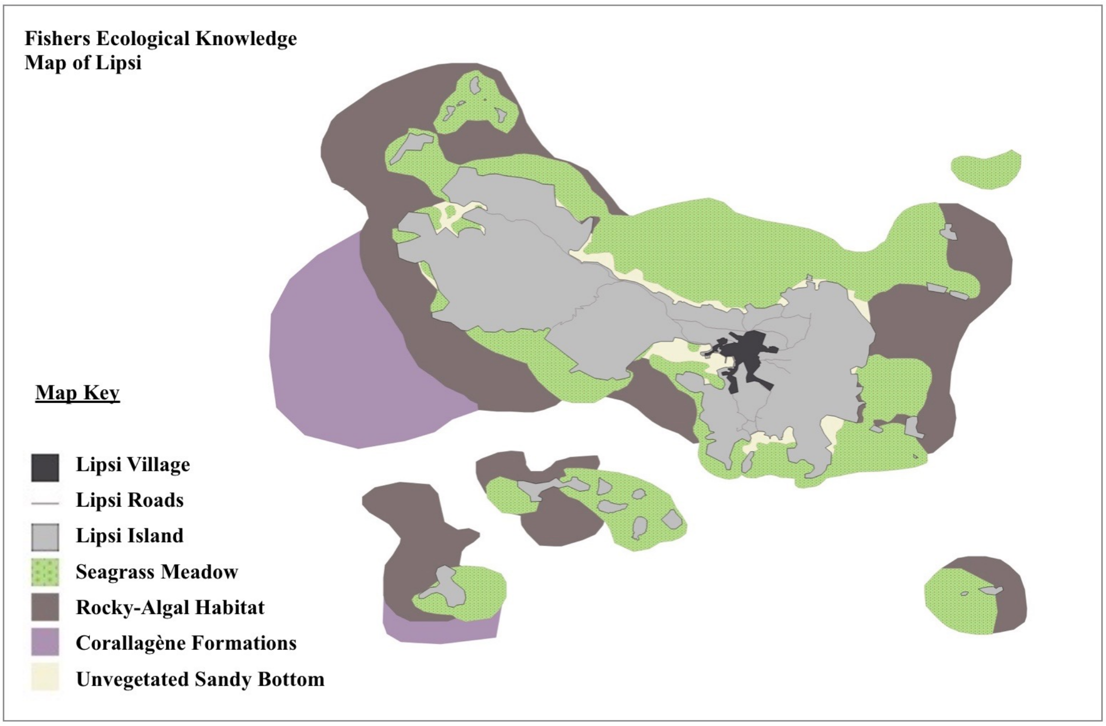


Figure 55. A composite fishers habitat map of Lipsi island and the surrounding coastal habitats established through outreach to Fishers Ecological Knowledge (FEK) and researchers (LEK). Habitat classes presented represent a composite of those identified by the fishers during the interviews.

The ≈100km^2 (99.6km^2 ±24.85) of the survey area mapped by fishers included exactly 17.35km^2 of landmass (Lipsi island), ≈24.25km^2 of *Posidonia oceanica* seagrass meadows ($seagrass_{TLEK}$); ≈23.58km^2 of rocky-algal habitats, ($rockyalgal_{TLEK}$); ≈12.26km^2 of Coralline algae formations ($coralline_{TLEK}$) and ≈11.55km^2 of un-vegetated Sandy Bottom ($sand_{TLEK}$) (Table 12). Blank space represents the ≈50.43km^2 of unknown habitat type. However, due to its depth and position in relation to the coastline (i.e. away from it) the area is likely to represent areas of largely smooth and flat substrate (FAO, 2008). Deeper areas without a habitat presented are likely areas of un-vegetated sandy-bottom / gravel (Pers. Obvs) which were likely not considered by fishers as distinctive 'habitats' during the interview process.

Table 12. Individual fisher estimates for habitat extent (km^2) around Lipsi.

COASTAL HABITAT	EXTENT (km^2)	OF TOTAL AREA (%)
FISHER 1		
Lipsi Island	17.35	11.57
Posidonia oceanica seagrass	26.50	17.67
Rocky-Algal habitat	25.57	19.05
Coralline algae formations	17.66	11.77
Unvegetated sandy bottom	11.55	7.70
Unreported	48.37	32.25
All habitats	**98.63**	**67.75**
Total Survey Area	**150.00**	**100.00**
FISHER 2		
Lipsi Island	17.35	11.57
Posidonia oceanica seagrass	21.46	14.31
Rocky-Algal formations	19.20	12.80
Coralline algae formation	5.64	3.76
Unvegetated sandy bottom	11.55	7.70
Unreported	74.80	49.87
All habitats	**75.20**	**50.13**
Total Survey Area	**150.00**	**100.00**
FISHER 3		
Lipsi Island	17.35	11.57
Posidonia oceanica seagrass	24.80	16.53
Rocky-Algal formations	25.98	17.32
Coralline algae formation	13.47	8.98
Unvegetated sandy bottom	43.27	28.85
Unreported	25.13	16.75
All habitats	**124.87**	**83.25**
Total Survey Area	**150.00**	**100.00**

Table 13. Combined fisher estimated habitat extents (km^2) around Lipsi.

COASTAL HABITAT	EXTENT (km^2)	OF TOTAL AREA (%)
Lipsi Island	17.35	11.57
Posidonia oceanica seagrass	24.25	16.17
Rocky-Algal formations	23.58	15.72
Coralline algae formation	12.26	8.17
Un-vegetated sandy bottom	11.55	7.70
All reported habitats	**88.99**	**59.33**
Un-reported habitats	61.01	40.67
Total Survey Area	**150**	**100.00**
Coastal Zone Area	**132.65**	**88.4**

At this spatial scale the habitat type categorised as *Posidonia oceanica* seagrass (*$seagrass_{TLEK}$*) is discontinuous within its range (Infantes et al, 2009; Borg et al., 2009), and thus reporting it here as such would significantly overestimate its extent. For this reason, a quantitatively informed adjustment of total seagrass habitat extent can be calculated by input from the results of Aerial Remote Sensing (see 6.4.4 "Synergies and Triangulation").

5.4.2 Aerial Remote Sensing (Site Scale)

Orthomosaic creation

Orthomosaics were produced for seven of the nine study sites (Figure 80). The UAV could not be used to capture images above the site Papadria, (Site 'g') due to the high numbers of recreational boat users present in the bay (see UK Civil Aviation Authority "DroneCode" code of conduct).

In addition to Papadria, there are no PhotoScan orthomosaics available for Kampos; the software was unable to align photos to build an effective point cloud. This was also the case for the missing patches within orthomosaics (c), (e) and (f) where the software was unable to match points and thus align photos successfully (Figure 81).

Figure 56. A map of Lipsi showing the location of a) successful UAV mapping (white circle) and b) unsuccessful UAV mapping (red circle).

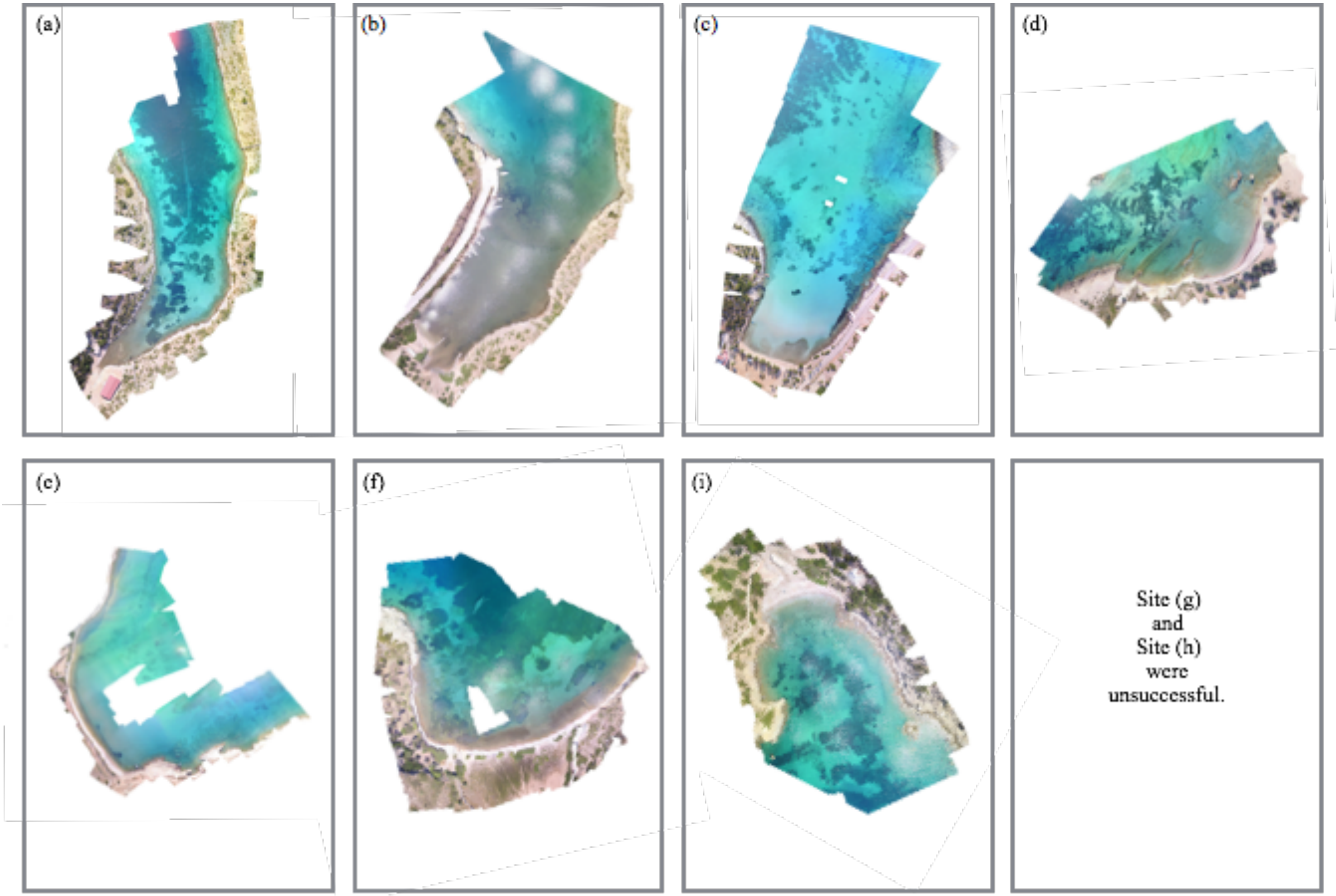


Figure 57. AgiSoft PhotoScan Pro orthomosaic maps of seven of the nine sites surveyed.

This was likely an artefact of wind driven water surface reflections and high contrast between adjacent photos. Time restraints during field time made the collection of further photos impossible, but future aerial surveys to accumulate more photos (in less windy conditions) would remove these gaps.

The eight sites surveyed were mapped after approximately 200 minutes of flight. In total this provided 621 photographic images that were used to produce the 3D point clouds, mesh's and textured models. These orthomosaics were then georeferenced and exported onto a Google Maps baselayer in QGIS (Figure 82) providing visualisation of coastal habitat distributions that were previously unavailable.

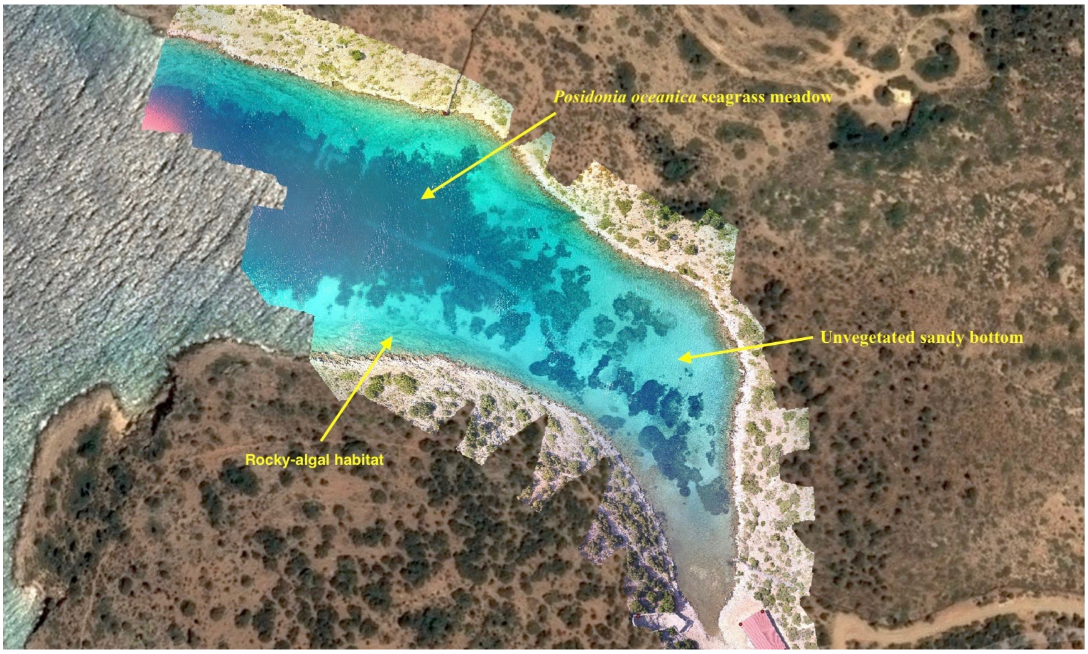


Figure 58. A Google Maps™ satellite baselayer in QGUS showing the successful export of a georeferenced orthomosaic layer derived from photographic images

Multispectral Analysis

After supervised collection of training signatures (see appendix), orthomosaics were classified into 3 major habit types – *Posidonia oceanica* seagrass, rocky-algal habitats and un-vegetated sandy bottom (Figure 83).

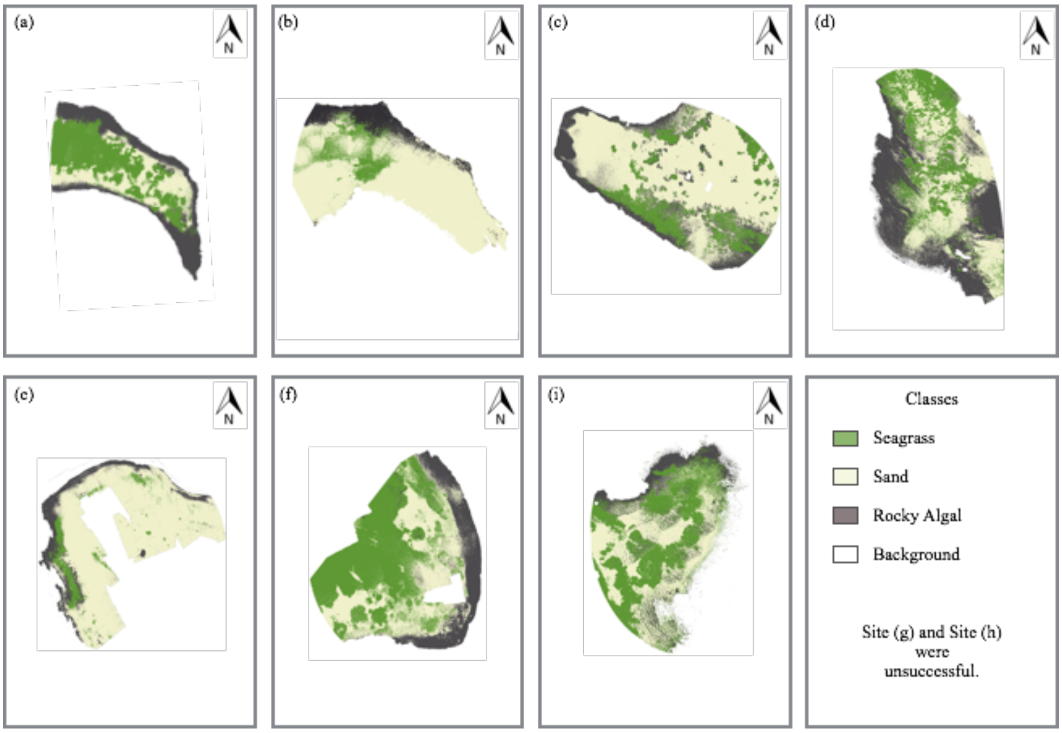


Figure 59. MultiSpec orthomosaic analysis showing habitat delineation (green = seagrass, grey = rocky-algal, beige = sand)

Results show that the density of *Posidonia oceanica* meadows, the texture of rocky-algal habitat, the depth of the substrate and the evenness of the water surface all influence the ability of the multispectral data analysis software to delineate habitat types. For example, in successfully classified images it was observed, that in some places sparse/patchy seagrass meadows (with exposed rhizome) were occasionally wrongly classified as rocky-algal habitat (or vice versa) (Figure 84).

To address these inaccuracies, re-examining of habitat classification using 'training classes' (see Methods Appendix) was necessary for comparison against classified files. In some cases, it was necessary to choose classes that 'best represented' known habitat distributions.

For this reason, accuracy assessments were occasionally considerably below the 'ideal' (>95%) targets for Producer Accuracy (PA) and Users Accuracy (UA) (Table 13). Across sites, for classified results using Quadratic Likelihood (MLC), PA varied from lows of 55.8 % for rocky-algal habitat, to 85.4% for seagrass and 84.4% for sand. This figure represents the software's estimate of the probability of the habitat areas being correctly classified. UA ranged from lows of 22.1 % for sand, to 10.2 % for seagrass and 35.4% for rocky-algal. This represents the probability that a category classified on map represents the actual category on ground (Table 13). On 25 of 42 (59.5%) occasions a figure of >95% was achieved. On 37 of 42 (88%) of occasions a figure of >80% was achieved. The lower accuracies found were due to mixing of spectral signatures of these classes which may have resulted in misclassification.

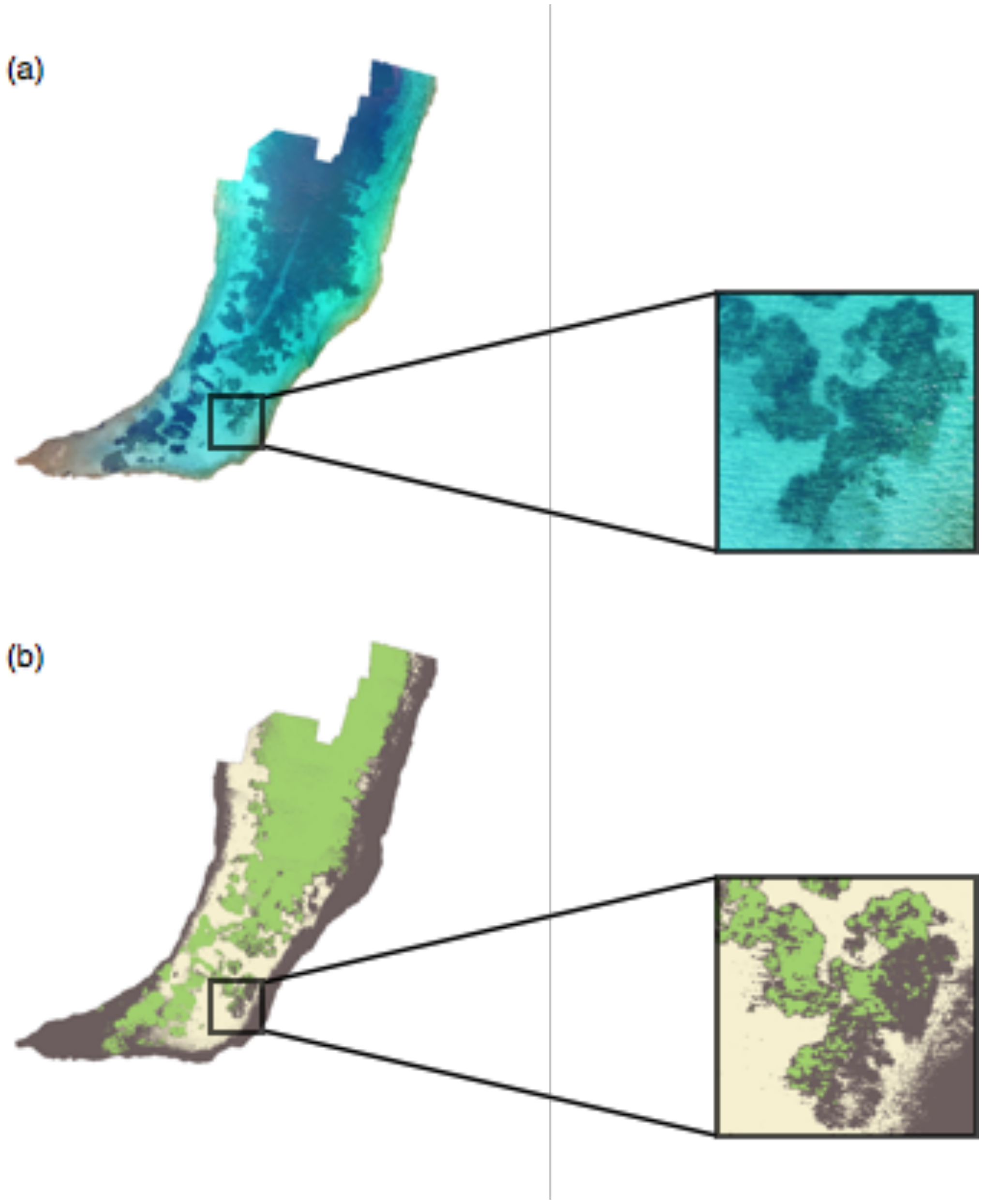


Figure 60. Areas of (a) patchy *Posidonia oceanica* seagrass often exhibited areas of exposed rhizome. This rhizome has a spectral signature (b) similar to that of rocky-algal habitat.

Table 14. Accuracy assessment results for classified images based on Quadratic Likelihood (Maximum likelihood classifier). PA = producer's accuracy (reference accuracy) UA = user's accuracy (reliability accuracy). OCA = Overall Class Accuracy

Class (Habitat)	Vroulia (a)		Moschato (b)		Platis Gialos (c)		Kamares (d)		Chochlakoura (e)		Limnh (f)		Kimissi (i)	
	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)
Seagrass	98.9	99.9	96.7	99.7	98.1	97.9	97.6	96.3	97.7	**10.2**	90.8	85.4	97.5	98.3
Rocky-Algal	98.0	99.6	99.1	85.3	**55.8**	80.5	97.8	84.5	75.2	**35.4**	88.8	86.3	99.5	97.1
Sand	99.9	95.8	96.0	89.4	94.1	**22.1**	91.0	99.1	84.4	99.9	92.9	98.0	99.2	99.6
Background	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
OCA (%)	98.9		97.8		93.4		96.7		88.9		94.2		99.7	
Kappa coefficient (%)	98.4		96.3		80.3		95.3		80.7		92.1		99.3	

Table 15. Class (habitat) distribution for sites showing habit area coverage (ha), and relative percent cover for the site (%). ALP = Average Likelihood Probability.

Habitat	Vroulia (a)		Moschato (b)		Platis Gialos (c)		Kamares (d)		Chochlakoura (e)		Limnh (f)		Kimissi (i)	
	Area (m^2)	Cover (%)	Area (m^2)	Cover (%)	Area (m^2)	Cover (%)	Area (m^2)	Cover (%)	Area (m^2)	Cover (%)	Area (m^2)	Cover (%)	Area (m^2)	Cover (%)
Seagrass	6,517	41.5	1,854.7	11.7	6,101.7	17.0	4,372.7	25.2	146.4	5.1	8,617.8	46.2	6,517.2	44.9
Rocky-Algal	5,081	32.3	2,092.1	13.3	7,242.7	20.3	6,721.3	38.7	934.3	32.5	3,499.5	18.8	5081.5	17.3
Sand	4,122	26.2	11,865.0	75.0	22,411.2	62.7	6,267.3	36.1	1793.6	62.4	6,524.8	35.0	4,121.9	37.8
TOTAL	15,720	100	15,811.8	100	35,755.6	100	17,361.3	100	2,874.3	100	18,642.1	100	15,720.6	100
ALP (%)	**86.0**		**83.1**		**81.7**		**79.4**		**76.6**		**76.9**		**79.1**	

Habitat Area Calculation

The relative habitat areas were calculated for of each of the sites (Table 15); from the coastline to the 9m depth contour. Total classified pixels were multiplied by the area coverage for individual pixel ($4.75cm^2$), this gives the overall habitat area coverage (Table 14).

Whilst, at $0.12km^2$ this represents an accurate mapping of less than 1% of the total area (≈$132.65km^2$) of the Lipsi coastal zone, this data represents a 'proof of concept' that UAVs can provide an effective methodology for detailed interrogation of specific sites of interest, and can provide the platform for subsequent extrapolation across spatial scales.

Table 16. Overall habitat areas as calculated by Unmanned Aerial Vehicle survey.

Overall Area	Area (m^2)	Area (ha)
Seagrass	$34,128m^2$	(3,41ha)
Rocky-Algal	$30,652m^2$	(3,07ha)
Sand	$57,106m^2$	(5,71ha)
Mapped Area	$121,886m^2$	(12.19ha)

5.4.3 In-situ observations (Patch Scale)

For Seagrass-Watch data all mean summary statistics were calculated with standard error. Water clarity (visibility) ranged from 15m-25m at each site and water temperature varied between 15°C and 26°C according to season and depth. Water clarity and temperature were therefore typically within physiological tolerances for *Posidonia oceanica* seagrass. In-situ observations pertaining to seagrass i) canopy height, ii) percentage cover, iii) epiphyte cover and iv) algae cover (Figure 85) enable the previously established '*size and distribution*' of recorded meadows (TLEK and ARS) to be contextualised by quantitative indicators of seagrass '*health*'.

Figure 61. In-situ observations allow for quantitative data to be collected regarding habitat characteristics.

Seagrass Canopy Height

Seasonal (temporal) variability is presented for canopy height (Figure 86). The site Chochlakoura was excluded from analysis because it was not possible to conduct seagrass assessment (by this method) at the site across all seasons. Across sites, the maximal mean canopy heights were observed in Summer (Jun-Aug), declining in Autumn (Sep-Nov), and recovering again from Winter (Dec-Feb), through to Spring (Mar-May) when growth of the seagrass was again recorded. One-way ANOVA revealed a statistically significant difference between seasons (across sites). Tukey's post-hoc test revealed that there was a significant difference between Winter and Spring (p = 0.001) and Winter and Summer (p = 0.001), but no significant difference between Winter and Autumn (p= 0.467). Summer was significantly different from all other seasons (p =0.001).

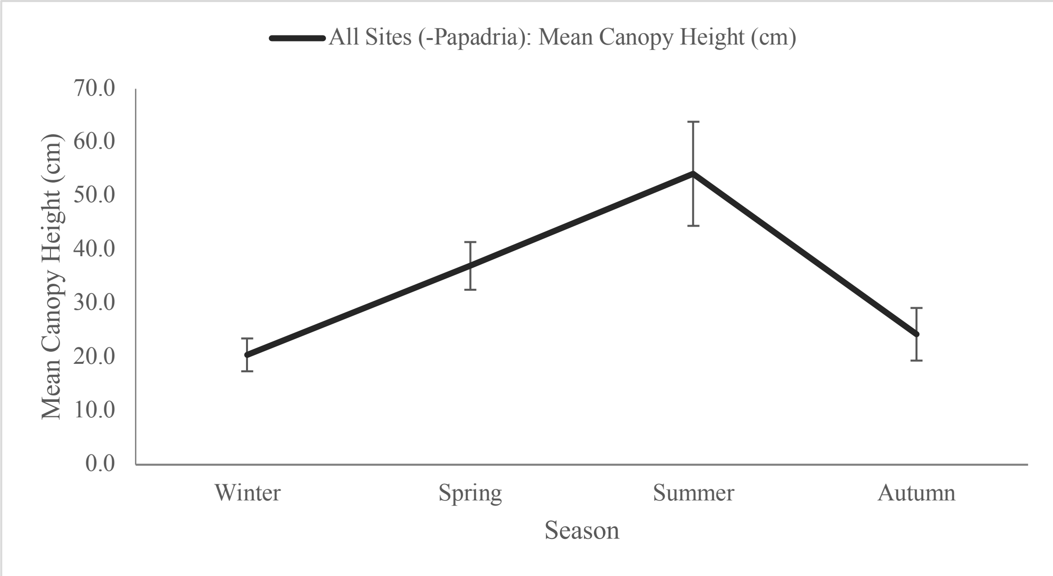


Figure 62. Mean canopy height (cm) for *Posidonia oceanica* seagrass habitat (±SE) over four seasons

Posidonia oceanica showed strong seasonality in mean canopy height, from 20.5cm (±3.1) in Winter, to 54.2cm (±9.69) in Summer. In Winter, the highest mean canopy height was recorded at Kambos 23.4cm (±7.1) compared to at Papadria where it reached 13.5cm (±5.1). In Summer, the highest mean canopy height was recorded at Limnh; 59.3cm (±7.3), whilst at Papadria mean canopy height reached just 30.4cm (±14.7).

Papadria displayed the lowest mean canopy height across all seasons, but this difference was not statistically significant. (p =0.799). However, high variability in canopy height was found at this site between individual quadrats, particularly in the summer survey; 9.3cm to 59.3cm. Such a range is indicative of a highly heterogeneous meadow. This can likely be attributed to the repetitive seasonal anchor damage from tourists' recreational vessels during summer (Francour et al., 1999; Milazzo et al., 2004) (see Chapter 9).

These findings are consistent with expected northern hemisphere seasonality and are consistent with findings reported from the western Mediterranean by Garcia and Duarte (2001). Overall, for canopy height, there was no statistically significant difference between sites (across all seasons); as determined by one-way ANOVA ($F_{7,24}$ = 0.479, p =0.840).

Seagrass Percentage Cover

There was no statistically significant difference between seasons (across sites) for seagrass percentage cover as determined by one-way ANOVA ($F_{3,32} = 0.315$, $p = 0.814$). However, ANOVA revealed a statistically significant difference between sites (across seasons) ($F_{8,27} = 10.411$, $p = 0.001$) (Figure 87). Tukey's post-hoc test revealed that Kampos 40.1% (±14.1) had significantly higher seagrass cover than all other sites except Limnh ($p = 0.700$); 30.6% (±8.6), and Kimissi ($p = 0.649$); 30.2% (±8.9). Chochlakoura 1.5% (±2.9) has significantly lower seagrass cover than all other sites except Platis Gialos ($p = 0.987$); 6.6% (±4.8).

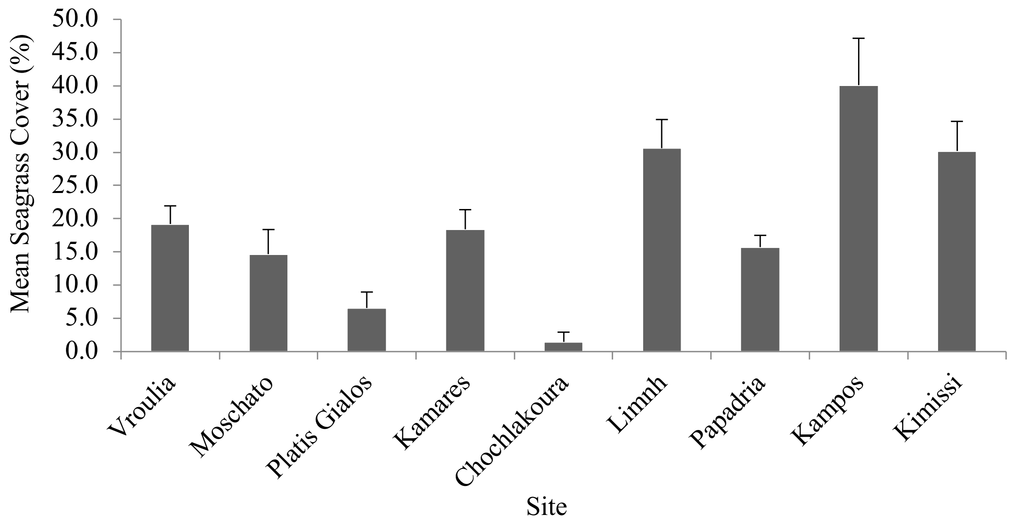


Figure 63. Mean (±SE) seagrass cover (%) by Lipsi island Seagrass-Watch site.

Mean seagrass cover was highest in the undisturbed bays of Limnh (30.6% ±8.6), Kampos (40.1% ±14.1) and Kimissi (30.2% ±8.9), whilst the lowest occurred in the sandy embayment's of Platis Gialos (6.6% ±4.8) and Chochlakoura (1.5% ±2.9). Intermediate cover was present in the rocky bay at Kamares (18.4% ±5.9), likely due to unfavourable substrate for *Posidonia oceanica* growth. Intermediate cover was also present in the highly anthropogenically impacted bays of Papadria (15.7%±3.5); likely reduced from anchoring, and Vroulia (19.2% ±5.5); likely reduced from coastal development and associated sedimentation, and Moschato; likely reduced due to eutrophication from the previous aquaculture farm (14.7% ±7.4) (see Chapter 3). Although no baseline data for these bays exist, it can be reasonably expected that these bays would have previously exhibited much higher seagrass cover than they do presently.

Seagrass Epiphyte Percentage Cover

A richer understanding of the '*health'* of reported seagrass cover (relating to meadow supply chain productivity) can be gained from examining epiphyte cover and algal cover variables (Figure 88). The presence of a variety of fertilizers from agricultural run-off can lead to nutrient over-abundance and the development of high numbers of epiphytes in those meadows receiving concentrations of such organic pollutants. Under such conditions, the epiphyte concentrations reduce the capacity for photosynthesis by blocking light and reducing the diffusion rate of CO_2 to the seagrass (Silberstein et al., 1986). As such epiphyte cover can be considered an indicator of organic pollutant levels (Pergent-Martini et al., 1995).

Figure 64. Epiphytes are sessile organisms that grow on plants (light green algae attached to seagrass). Epiphytes form the basis of several food webs within seagrass species assemblages.

There was no statistically significant difference between seasons (across sites) for seagrass epiphyte cover as determined by one-way ANOVA ($F_{3,28}$ = 2.066, p = 0.127). However, ANOVA revealed a statistically significant difference between sites (across seasons) ($F_{7,24}$ =7.421, p = 0.001). Tukey's post-hoc test revealed that epiphyte cover was significantly higher at Vroulia (50.6% ±27.0) and Moschato 67.8% (±16.0) than at Platis Gialos 27.0% (±27.0) and Kamares 15.0% (±17.9), but neither site was significantly different from Limnh, Papadria, Kampos or Kimissi.

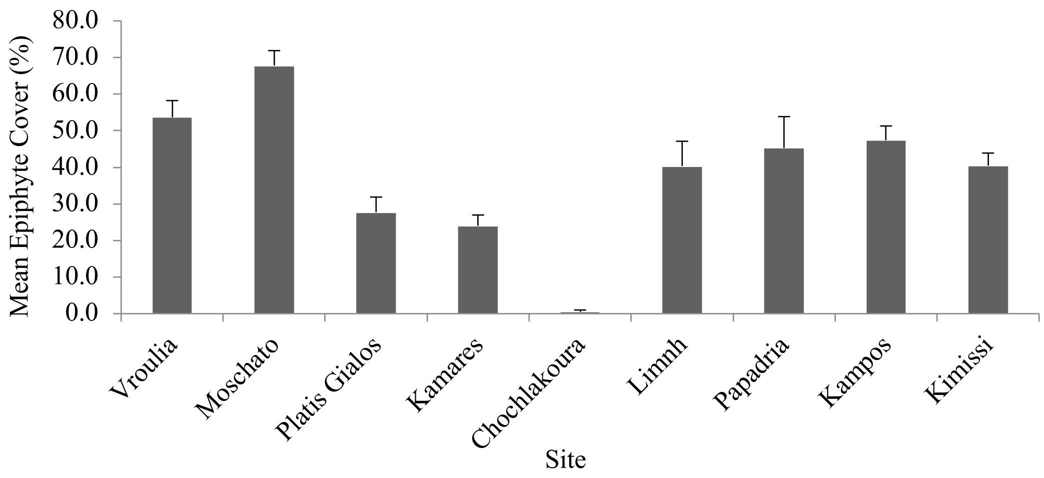


Figure 65. Mean (±SE) seagrass epiphyte cover (%) by Lipsi island Seagrass-Watch site.

Chochalkoura was without recorded seasonal seagrass coverage and is thus excluded from statical analysis. The exceptionally low score presented for mean epiphyte cover (Figure 89) at Chochlakoura (0.5%) can be attributed to the recorded presence in only one of four seasons (an artefact of there being very little *Posidonia oceanica* at the site). Elsewhere epiphyte cover falls in the range of 24% (±5.9) to 47.4% (±7.8) with variation likely to be attributable to a variety of factors, not least the impact of Nitrogen and Phosphorus fertilizers from local farms – known to be used extensively by countries of the eastern Mediterranean basin (Karydis and Chatzichristofas, 2003).

Algal Percentage Cover

Extensive algal growth can be an indicator of a degraded seagrass ecosystem. This is because seagrass exhibits much slower growth rates to that of algae. Figure 90 shows two algae species that are a problem in the Mediterranean Sea. Algae are efficient at exceeding regular growth limits under high nutrient conditions through much higher uptake rates (Duarte, 1995).

(a) 

(b) 

Figure 66. Two algal species were noted in this study (a) *Caulerpa racemosa* (Forsskål) and (b) *Caulerpa prolifera* (Forsskål). Images © AlgaeBase (www.algaebase.org).

There was no statistically significant difference between seasons (across sites) for algal cover as determined by one-way ANOVA ($F_{3,32} = 0.048$, $p = 0.986$). However, one-way ANOVA revealed a statistically significant difference between sites (across seasons) ($F_{8,27} = 56.309$, $p = 0.001$). Tukey's post-hoc test revealed that algal cover was significantly greater at Moschato ($p = 0.001$); 63.5% (±6.6) than all other sites. Kampos recorded the lowest algal cover 2.0% (±1.5) but was not significantly different from any other sites, with the exceptions being Kimissi 15.5% (±8.3) and Moschato (Figure 91).

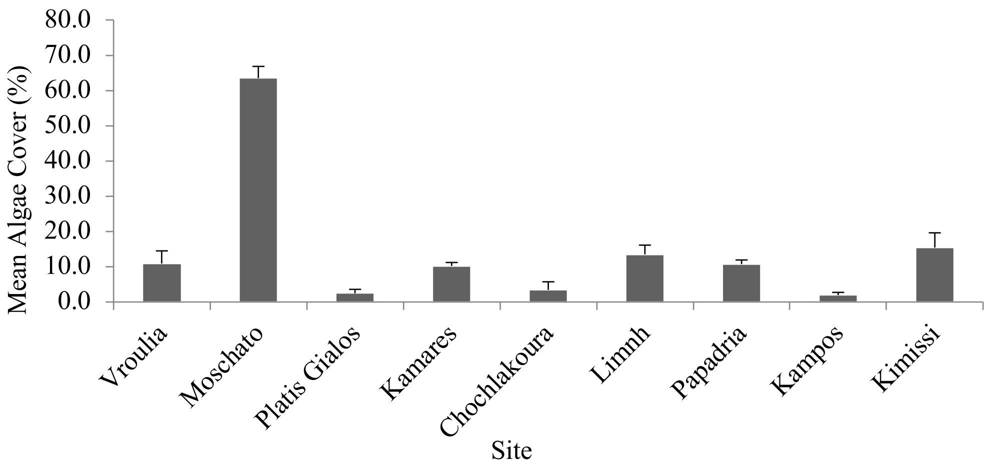


Figure 67. Mean (±SE) algal cover (%) by Lipsi island Seagrass-Watch site.

The high epiphyte cover scores in Moschato (67.8% ±8.1)) and adjacent Vroulia (53.7% ±9.1) are likely a legacy of the aquaculture facility. Intensive fish farming results in the production of waste, which stimulates algal growth (Karydis and Chatzichristofas, 2003).

5.4.4 Synergies and Triangulation (Multi-Scale)

Triangulation

Posidonia oceanica is continuous at depths of 10-30m, but reticulate at depths of less than 10m, and between 30m-50m (Borg et al, 2009; Infantes et al, 2009). In this study <10m was the depth range in which accurate habitat mapping was conducted by Aerial Remote Sensing (Figure 92).

A quantitative assessment by ARS of the relative habitat composition from each of the sites allowed for an accurate estimation of the relative habitat cover (seagrass / rocky-algal / sand) for the 0-10m depth range. Whilst the figure calculated here for the 0-10m depth range likely represents an underestimation of true habitat extent in the 10m-30m depth range, it likely reflects a good proxy for habitat extent in meadows between 30-50m. For this reason it was used as a proxy and to contextualise data gathered from Traditional and Local Eecological Knowledge (TLEK).

Figure 68. ***Posidonia seagrass is not continuous in its reported habitat range*** **(seagrass$_{TLEK}$) and therefore an estimate of ¼ of the total area reported is used for calculating true habitat extent.**

Calculation of the combined habitat extent from each of the mapped sites generated a relative seagrass coverage figure of 30.0%, therefore actual cover represents closer to one third of the total reported seagrass area as presented by TLEK. This figure was calculated from the mean habitat covers identified at sites by ARS apart from Moschato (Table 16). Moschato is degraded and represents a highly anomalous seagrass distribution; it is therefore not included.

Table 3. MULTISPEC data from Aerial Remote Sensing at six sites around Lipsi.

SITE	HABITAT COVER (%)		
	Seagrass	Rocky-algal	Sand
Limnh	46.2	18.8	35.0
Kimissi	44.9	17.3	37.8
Kamares	25.2	38.7	36.1
Vroulia	41.5	32.3	26.2
Chochlakoura	5.1	32.6	62.4
Platis Gialos	17.0	20.3	62.7
Mean Totals	**30.0**	**26.7**	**43.4**

The additional 70% of intermittent habitat described as "seagrass" in *seagrass*$_{TLEK}$ but isn't, is presented as 'unspecified intermittent habitat' (Table 17). The UAV informed and adjusted extents of local habitat types as reported from outreach to TLEK are therefore presented in Table 17.

Table 4. Estimated habitat extents around Lipsi island as estimated from Fishers Traditional and Local Ecological Knowledge.

COASTAL HABITAT	EXTENT (km^2)	OF TOTAL AREA (%)
Lipsi Island	17.35	11.57
Posidonia oceanica seagrass	24.25	16.17
(Actual seagrass cover)	*(7.28)*	*(4.85)*
(Unspecified Intermittent habitat)	*(16.97)*	*(11.32)*
Rocky-Algal formations	23.58	15.72
Coralline algae formation	12.26	8.17
Un-vegetated sandy bottom	11.55	7.70
All reported habitats	**88.99**	**59.33**
Un-reported habitats	61.01	40.67
Total Survey Area	**150**	**100.00**
Coastal zone Area	**132.65**	**88.4**

From this data, a conservative estimate suggests that a 5.5% of the identified Lipsi coastal zone is surface area is *Posidonia oceanica* seagrass meadow (7.28km^2 / 132.65km^2 x 100). However, more broadly, this 'reticulate seagrass habitat' covers an area of just over eighteen percent (18.2%) of the total coastal zone. In addition, 9.2% of the identified coastal zone is reported to be Coralline algae formations. Both these habitats are "*high priority*" habitats for Mediterranean marine reserve creation (Giakoumi et al, 2011) due to their importance for marine biodiversity in their associated species assemblages.

In contrast 17.7% of reported habitat are rocky-algal formations. These habitats are generally "*low priority*" habitats, except in cases where there are forests of specific macroalgae e.g *Cystoseira* (undocumented) or where there are breeding caves for the Mediterranean monk seal (*Monahcus monachus*) (Giakoumi et al., 2011). On Lipsi there exist Mediterranean monk seal caves on Makronissi and the surrounding islets (Pers. Obvs). This knowledge would also make this area also a "high priority" for marine reserve creation.

Through utilising TLEK to create a typology of habitats present in the Lipsi coastal zone, and by supplementing this data with both high resolution photographic image analysis (see ARS data) and in-situ observations (see ISO data), has allowed for the characterisation of the sites of interest *'from both geomorphological and biological point of view'* (Ventura et al., 2016).

For example, in all cases (except for uncharacteristic Moschato) ARS mapping by UAV recorded higher seagrass percentage cover than ISOs (Seagrass-Watch method). This is likely an artefact of the 50m x 50m limit of the Seagrass-Watch protocol operating within shallower waters (normally <5m) and the majority of the more continuous *Posidionia oceanica* seagrass meadows occurring as the 10m depth contoured was neared. This also helps to explain the low percentage cover estimate from Seagrass-Watch at Vroulia, since the heavy sedimentation in the shallows of this site (Figure 83, site 'a') would have a greater influence on ISO estimations than ARS.

Table 5. Triangulated data is presented. Sites data is presented with coordinates, descriptions, and identified threats (as established by ARS and ISO). Figures in bold and underlined represent statistically significant differences identified from the data.

Traditional and Local Ecological Knowledge (TLEK: "Mind Maps")		Aerial Remote Sensing (ARS: "UAV Orthomosaics and MultiSpectral Analysis")				In-Situ Observations (ISO: "Seagrass-Watch")				
Habitat Types	**Estimated Habitat Cover (m²)**	**Site Coordinates (GPS)**	**Site (Name)**	**Calculated Seagrass Cover (m²)**	**Relative Seagrass Cover (%)**	**General Description (Sediment)**	**Mean Seagrass Cover (%)**	**Mean Epiphyte Cover (%)**	**MeanA lgae Cover (%)**	**Mean Canopy Height (cm)**
		37°19.005'N 26°43.003'E	(a) Vroulia	6,517	Medium (41.5)	Degraded seagrass (sand/mud)	19.2	53.7	10.9	35.6
(1) *Posidonia oceanica*	242,500	37°19.077'N 26°43.004'E	(b) Moschato	1,855	Low (11.7)	Degraded seagrass (mud/algae)	14.7	**67.8**	**63.5**	36.3
		37°18.504'N 26°44.222'E	(c) Platis Gialos	6,102	Low (17.0)	Sandy Bay rock/sand	6.6	27.7	2.5	35.2
(2) Rocky-algal habitat	235,800	37°18.196'N 26°47.166'E	(d) Kamares	4,373	Medium (25.2)	Rocky-Bay (rock/rubble)	18.4	24.0	10.2	34.4
		37°17.085'N 26°47.003'E	(e) Chochlakoura	146	Low (5.1)	Sandy Bay (sand)	1.5	0.5	3.4	No data
(3) Un-vegetated sandy bottom	115,500 (*Reported*)	37°16.823'N 26°46.721'E	(f) Limnh	8,618	High (46.2)	Seagrass meadow (rock/sand)	30.6	40.3	13.5	36.5
		37°16.822'N 26°46.147'E	(g) Papadria	No data	No data	Degraded seagrass (rock/sand)	15.7	45.3	10.8	**20.9**
(4) Corallagène formations	122,600	37°17.918'N 26°45.530'E	(h) Kampos	No data	No data	Seagrass meadow (rock/sand)	40.1	47.4	2.0	35.7
		37°18.141'N 26°44.976'E	(i) Kimissi	6,518	High (44.9)	Seagrass meadow (rock/sand)	30.2	40.5	15.5	37.4

Critically whilst ARS can provide more accurate figures for overall habitat cover, it is still unable to provide detail pertaining to canopy height or epiphytic/algal coverage which is only achievable in-situ. ISOs enable explanations to be proposed for the observed phenomenon.

For example, Moschato (Figure 83, site ‘b’) shows a markedly different spectral signature to other habitats, and seagrass cover is noticeably reduced in comparison to adjacent bays. ISOs also revealed significantly higher algal (both free standing and epiphytic) coverage which is a clear indicator of eutrophication in the bay.

The lower mean canopy height presented at Papadria, and the relatively lower mean seagrass cover in comparison to adjacent bays, when taken in conjunction with the observations of exposed rhizome in the bay, and the documented evidence of recreational vessels anchoring, all point to the loss of seagrass due to physical erosion from anchoring.

5.5 Discussion

The results from this chapter are presented from multiple spatial scales (Local, Site and Patch) which allows for the presentation of data elements and the extrapolation of observed patterns between scales. Generally speaking, ISOs and measurements are better suited to the local study of elements, whereas ARS and data from TLEK is better suited to providing broader scale patterns, but both approaches complement each other. Comparisons between the data sets can be elicited for satisfactory (or otherwise) agreements between findings at one spatial scale to another (Wikle and Berliner, 2005). In this Chapter the data collected is intended to interrogate the relationship between broad habitat distributions (TLEK), the habitat spatial patterning within those distributions (ARS), and the habitat characteristics (IOS). Through this process, a richer understanding of coastal habitat '*Size', 'Distribution'* and '*Health'* has been achieved (Table 18).

To explore the habitats 'Resilience' would need further data collection that was unachievable within the scope of this study (see Unsworth et al, 2015, for full discussion and a seagrass resilience framework). In this chapter, interrogation of the distribution and characteristics of habitat adopted a place-based approach, with habitat distribution interrogated over three spatial scales: The local (TLEK), the site (ARS) and the patch (ISO). Through this approach spatial and temporal data relevant to effective SSCF SSCM was documented at each scale enabling a more holistic understanding of habitat spatial patterning and current health.

Initial outreach to fishers was useful both as a medium for understanding how fishers interpreted their local habitats, but also as a rapid, 'basic' approach (sensu Roelfsema and Phinn, 2010) to achieving large scale spatial data. Despite its limitations, this is an important contribution, especially when considering data limitations in Greece (Telesca et al., 2015) and the ever-increasing need for the integration of habitat monitoring data in geographic information systems (GIS) (Franklin et al., 2003; Ventura et al., 2006).

TLEK integration also represents a complementary, cheap and alternative method to more traditional scientific approaches, for those areas (such as is the case in Greece) where coastal ecosystems are both vulnerable and rapidly changing, and where local resource managers lack data (Beaudreau and Levin, 2014).

The quality and quantity of UAV systems now available at more accessible prices are opening the possibility to researchers for rapid and accurate habitat mapping across large spatial scales. Contributions to methods are coming from several fields including terrestrial ecology (Wallace et al., 2016; Fraser et al., 2016), geology (Clapuyt et al., 2016), and marine ecology (Ventura et al., 2016). Ventura et al. (2016) state that it:

'*seems necessary* to develop a '*low-cost method of remote acquisition'* at least with regard to the '*identification and description of coastal inshore habitats'*.

In this study one of the initial goals of 'trialling a low-cost drone based application for identifying and mapping of coastal habitats' can be deemed successful. The methods presented are consistent with other authors (see Ventura et al., 2016) working in similar environments and therefore aerial remote sensing of this nature should be pursued for the mapping of priority marine coastal habitats.

This contribution can help to articulate the challenges of utilising such technology i.e. avoiding use in windy environments and timing flights to avoid surface reflections in photographic images present due to the angle of the sun, and solutions i.e. planning flights around prevailing weather conditions so as to operate in sheltered locations (lee of the island) and flying early in the morning and late at night so that surface reflections are not captured by the camera.

In this study, ISOs enabled the accurate recording of multiple factors, but of primary concern to this study are the indicators of habitat 'health' as quantified by seasonal changes in seagrass canopy height, and the site variations pertaining to seagrass and algal cover. The Seagrass-Watch ISO data create a 'snapshot in time' of the seagrass characteristics at each patch, and thus provide an indicator of seagrass health at any given point (in this case season) in time. Critically, the collection of morphometric data (i.e. blade length) revealed clear seasonality pertaining to canopy height, with growth from winter, through spring and into summer. In the autumn, when sea storms occur, there is an associated loss of leaves and epiphyte cover, a finding consistent with trends from previous studies (Pergent-Martini et al., 1995). It is for this reason that habitat comparisons that explore seagrass morphometic changes to the meadow should be conducted over longer temporal scales e.g. between years and not between seasons within a year. Such data also supports data collection pertaining to seagrass meadow resilience such as seagrass carbohydrate stores or meadow seed banks (see Unsworth et al, 2015).

In contrast, observations pertaining to seagrass percentage cover showed no significant difference between seasons. Together, these findings suggest that whilst there is significant vertical change in seagrass canopy height, there is no significant change in horizontal seagrass distribution over the course of an annual cycle. These findings have implications for how these habitats are seasonally utilised by marine species i.e. likely little change 'gap crossing' behaviours between patches of seagrass (see Ryan et al, 2012) but likely a change in seasonal use of habitat with a change in the seasonal 3D structure (see Heck et al, 2003). This would therefore have implications for seasonal predictability of product supply into the local small-scale capture fisheries supply chain.

5.5.1 Relevance to Small-Scale Capture Fisheries Sustainable Supply Chain Management

Data presented within this chapter highlights some of the similarities and the some of the contrasts between 'suppliers' in SSCF SSCM and conventional SCM. For example: An understanding of the *'size and distribution'* of product suppliers is desirable for effective SSCM to answer questions such as: Where are the products physically coming from? How many products can each supplier provide? Equally, the '*health'* of product supply requires an understanding of the 'condition' of the suppliers: Are the suppliers able to continue this level of supply consistently? Will this level of provision continue indefinitely? The management challenges specifically relating to the SSCF that have been identified within this chapter are:

a) the inability of managers 'to command' changes in the *capacity* of product supply
b) the seasonal *variability* in product supply (linked to seasonal changes in the environment).

Together these factors result in relatively inconsistent and relatively unpredictable seafood product supply.

Size and Distribution

The 'carrying capacity' of a habitat is the maximum population size of a species that can be sustained indefinitely given the food, shelter and other necessities derived from the environment (Stalnaker, 1979). From a SSCM perspective, there is a direct correlation between the *size* and *distribution* of a productive habitat e.g. a seagrass meadow, and it's carrying capacity, and thus, unless extraction occurs, the habitat will become 'full' over time (Figure 93).

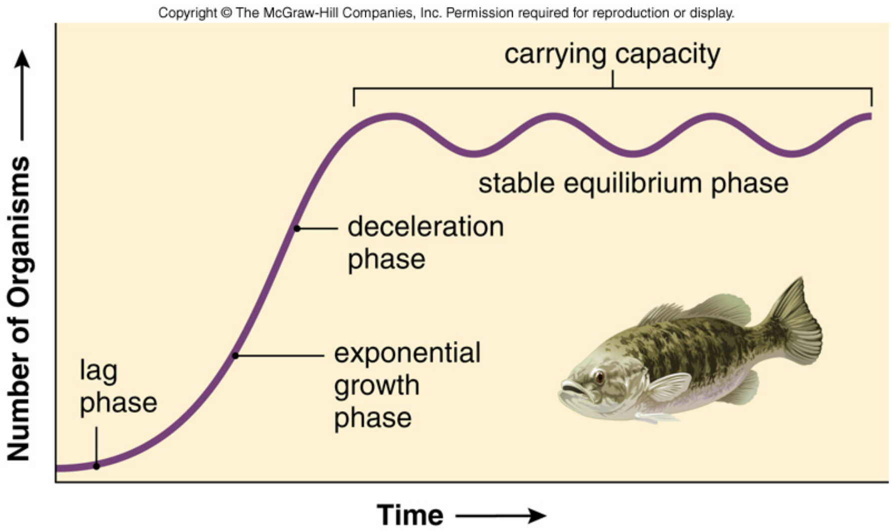


Figure 69. The carrying capacity of the environment is limited by the amount of appropriate habitat – over time the habitat will become 'full'

To increase the carrying capacity for productive seagrass habitats would principally require i) first an increase in the spatial extent of the habitats but then ii) the development of the habitat density, complexity and species richness (Figure 94) (or other such limiting factors).

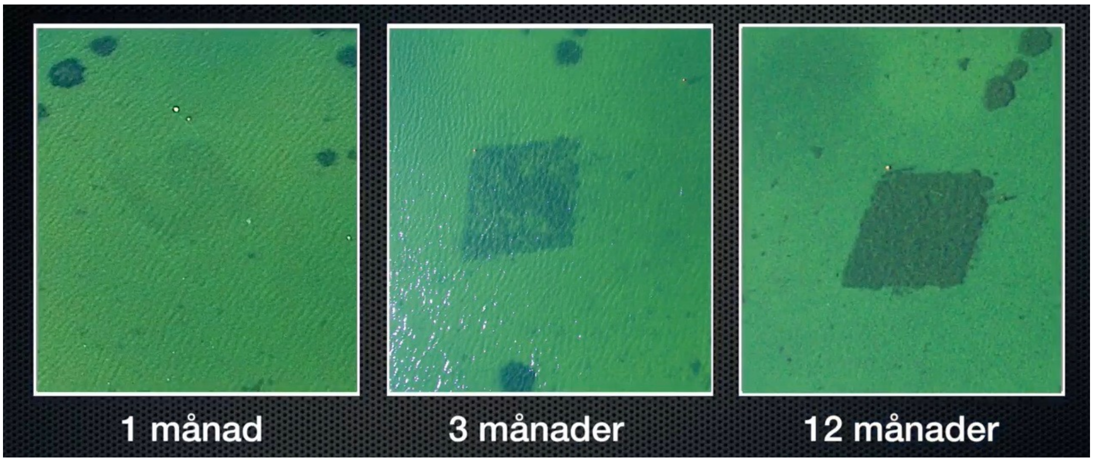


Figure 70. An aerial view of seagrass restoration from Göteborg Universitet, Sweden (ZORRO YouTube) showing the development of the habitat complexity over a 1, 3 and 12-month period.

However, in some cases, such as with the local *Posidionia oceanica* seagrass, which has the slowest horizontal growth ever reported for a seagrass species (Duarte, 1991) at about 1 to 6 cm yr^{-1} (Marbà et al, 1996), the spatial increase of habitat is very slow, and thus it is decidedly preferable to protect the habitat supply that already exists rather than trying to increase the supply capacity from provision of additional habitat.

The limited capacity for lateral colonisation (or recolonization) by *Posidonia oceanica* seagrass has been attributed to nutrient deficiency in adjacent sand patches (Duarte and Sand-Jensen, 1996), as well as factors relating to seed nutrient content and nutritional status of seedlings (Balestri et al., 2009). Regardless of the reason, what this means is that once *P. oceanica* habitat is damaged or degraded, it will take a long time to recover (if ever), with the implications being a reduced capacity and impacted sustainability of seafood supply.

A reduction in supply capacity linked to habitat loss is of concern to the Lipsi SSCF supply chain because in this study seagrass meadows were relatively intact at just two-thirds (Platis Gialos, Chochlakoura, Kamares, Limnh, Kambos, Kimissi) of the nine sites.

Health

From a SSCM perspective, there is also a direct correlation between the *health* of a productive habitat. In this study, the *health* of seagrass is expressed by the current physical condition of a meadow. However over time its *resilience* would be expressed by its capacity to withstand ‘stress’ and endure. Resilience strategy in *Posidonia* species is typically to develop large carbohydrate stores which they use to resist short or medium term disturbances (Marbà et al., 1996). Under optimal conditions, these species build stores of carbohydrate within their rhizomes which can be mobilised to sustain the plant temporarily during periods of stress, particularly stress that reduces net photosynthesis (Unsworth et al, 2015).

A degraded seagrass habitat or stressed system would also limit the carrying capacity (and thus product supply) of a given habitat type. If a habitat is in ‘good condition’ then the carrying capacity will be greater than if the habitat is degraded (Figure 95). If the habitat become so degraded it reaches a threshold value, then it will experience a regime shift into another stable state. This concept is classically articulated using an example from Mississippi State University’s “Deer Lab”.

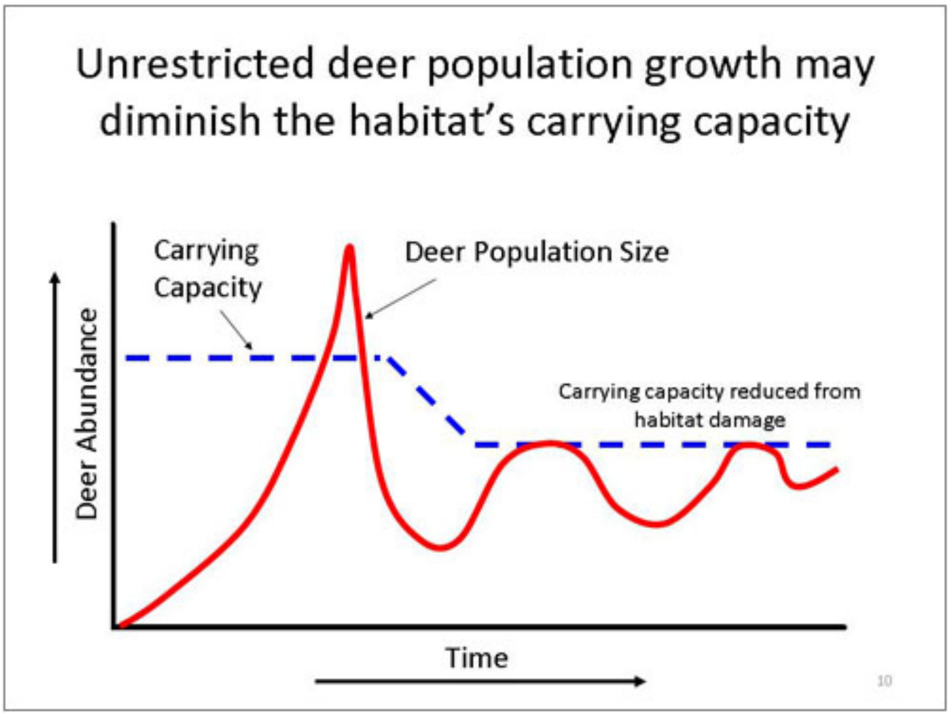


Figure 71. Carrying Capacity varies with a habitats condition (*health*) http://www.msudeerlab.com/mobile/carryingcapacity.asp.

In this example, whilst herbivory has not been studied, the condition of the seagrass meadows has been quantitatively assessed via Seagrass-Watch methods. This data is indicative of the seagrass meadow's current '*health'* and therefore a good proxy for understanding habitat mediated product supply. Of concern to the provisioning and management of the SSCM of the Lipsi SSCF supply chain, the site of Vroulia exhibited high epiphyte cover, which, whilst not necessarily a concern in isolation, could well put stress on the seagrass during periods of heavy rainfall and/or 'Meltemi' wind swell. At these times sedimentation from surface run-off (or resuspension) could limit light reaching the seagrass, and therefore the capacity for the plant to photosynthesise (testing its resilience).

At Moschato epiphytic algal cover was significantly higher than at other sites, and free-standing algal cover was also significantly higher, over seven times higher than the average across other sites. In addition, seagrass percentage cover was lower than neighbouring Vroulia suggesting that much seagrass has already been lost in this bay likely due to eutrophication, port development and associated sedimentation.

Here on Lipsi, it is likely that a regime shift is occurring. Regime shifts occur when the stressors can transform one ecosystem e.g. a seagrass ecosystem into another e.g. muddy sediment (see Rocha et al., 2015; Unsworth et al., 2015). Essentially, what once was a seagrass meadow no longer *looks* or *behaves* like a seagrass meadow! In Moschato, it cannot yet be confidentally described as a 'regime shift' just yet if there is still a viable seed bank, and conditions for their germination and growth are present, but further research would be required to determine this. The conclusion that there has been a regime shift in Moschato is supported by anecdotal evidence generated from TLEK which reports the presence of a *Posidonia oceanica* seagrass meadow in the bay prior to the introduction of an aquaculture facility.

At another site, marked meadow heterogeneity was witnessed with damage to meadows (exposed rhizome) at Papadria at 15.7% (±3.5). This site has less than half the seagrass cover of adjacent bays (e.g. Limnh; 30.6 ±8.6) supporting the qualitative observation of decline in its seagrass integrity and extent. Unfortunately (and somewhat ironically), complementary UAV data in the form of a habitat orthomosaic is unavailable to support the Seagrass-Watch data at this site due to the high numbers of recreational vessels anchored in the bay preventing drone mapping (Figure 96)

Figure 72. The Unmanned Aerial Vehicle was unable to be flown over the bay at Papadria because of the large volume of vessels present in the bay (UK DroneCode).

One of the greatest challenges in managing the SSCF supply chain is in understanding the seasonality involved in seafood product supply. Through collecting seasonal habitat data over the course of one calendar year it has been possible to describe the seasonal changes that can be expected regarding habitat characteristics e.g. seagrass canopy height. In isolation, this data may not seem to affect product supply, but it can provide important contextual data for understanding species-habitat associations and the characteristics of species assemblages recorded in later chapters (see Chapter 6).

Management of Lipsi's Small-Scale Capture Fishery

The map presented in Figure 72 represents Lipsi and the local area (≈150km^2). TLEK enabled approximately two-thirds of this area (≈99.6km^2) to be identified as one of five broad habitat types (Land, Seagrass, Rocky-Algal, Coralline algae, Sand). Of these identified habitats, two, totalling ≈36.51km^2 (or approximately one quarter of the total local area) represent "high priority" habitats (Giakoumi et al., 2011). Specifically, TLEK identified ≈24.25km^2 of seagrass meadows (representative of minimum continuous cover of ≈6.28km^2) and ≈12.26km^2 of coralline algae formations.

Giakoumi et al, (2011) identified the seagrasses *Posidonia oceanica* and *Cymodocea nodosa* and forests of the macroalgae Cystoseira as "high priority" critical habitats because they are *"important nursery grounds for many fish and invertebrate species"*. The importance of understanding '*priority habitat'* distribution and condition (sensu Giakouni et al, 2011) is thus predicated on the assumption that a greater extent of healthy coastal seagrass meadows will provide a greater supply of seafood into SSCF supply chains. The rationale for this is the knowledge that seagrass meadows support a greater abundance and diversity of fish (Ferrell and Bell, 1991, Jenkins et al, 1997, Guidetti 2000, Kalogirou et al., 2010) than adjacent bare sand habitats, and therefore the larger the meadow, the greater the number of fish that can be expected to feed into the supply chain.

A principal concern for the Lipsi SSCF is thus that the spatial extent and condition of priority habitats is currently being reduced by human behaviours. In particular, the absence of *Posidonia oceanica* around Lipsi can be directly linked to anthropogenic effects (e.g. anchoring / eutrophication). This chapter has established that seafood product supply is likely linked to the loss of seagrass habitat and that seagrass habitat recovery is potentially hindered by several factors such as competition for substrate, excessive nutrient loading and coastal development (Table 19):

Table 6. Table illustrating some of the Sustainable Supply Chain Management challenges relating to protection of productive coastal habitat.

Competition for substrate	Around Lipsi, the structurally small seagrass species of *Halophila stipulacea* and *Cymodocea nodosa,* as well as the algaesl *Caulerpa racemose* and *Caulerpa prolifera* were seen to colonise bare substrates adjacent to, or in areas within, damaged meadows of the structurally larger ecosystem building *Posidonia oceanica*, which would limit the opportunity for recovery of this species at any point.
Nutrient loading	In the bays of Moschato, and to a lesser extent, Vroulia, an increase in the abundance of algal epiphyte would also have trapped the finer sediment particles, reducing the light available to the seagrass (Dennison et al., 1993) and eventually causing the seagrass to be lost (McKenzie et al., 2007).

Coastal development	Increased coastal development, especially close to the shore is causing changes in both respective land-use and sea-use patterns in the coastal zone (e.g. increased recreational anchoring). Seagrass-Watch data at sites also bore witness to the reduced cover of seagrass coverage in bays where anchoring was at its most extensive. The popular 'sandy' bays of Chochlakoura and Platis Gialos experience heavy boat traffic over the summer months, but anchoring in sandy substrate has little deleterious effect on the habitat type. In contrast, the popular bay Papadria, with its once extensive seagrass meadow showed signs of extensive anchor damage with lower mean seagrass cover.

5.5.3 Management Recommendations

The application of multiple methods and multiple disciplines to coastal zone research is a relatively recent and evolving phenomena, with the 'jury still out' as to the most appropriate statistical and technical approaches for representing the dynamics of coastal zones (Boström et al, 2011; Barrell and Grant, 2015). Coastal environments are often highly dynamic in space and time which necessitates fine-resolution spatial data in order to capture patterns; but the patterns need to be at useful spatial scales to inform coastal management.

It is argued here, that through interrogation of the coastal zone through multiple methods (like those in this chapter), multidisciplinary researchers will play an important role in defining the habitats, and therefore the 'terms / units' under consideration in a given coastal zone. Indeed, it is the identification of several of these synergies that have informed the priorities for spatial prioritization in the eastern Mediterranean Sea (Giakoumi et al., 2011). Critically, it is the knowledge that Mediterranean seagrass meadows are important for fisheries, and that these meadows are at risk from human impact, that will inform the cost-effective prioritisation of actions to conserve coastal habitats Giakoumi et al., 2015).

From an SSCM perspective, the protection of productive habitat is essential for the continuity and flow of seafood products into the supply chain. The handling of risks to an industry's supply side has traditionally been linked to supplier quality problems, delivery failures and supplier financial defaults (Manuj and Mentzer, 2008). Here the common feature of such risks is that supply chain insecurity will materialise due to a disruption in the supply chain that obstructs the flow of products (Bode et al., 2011). Much business and management literature concerning supply chain 'risk management' presents examples of best practices, guidelines and concepts of how to either minimize the causes of disruptions (cause-oriented risk management) or to mitigate the adverse effects induced by disruptions (effect-oriented risk management) (Hofmann et al., 2014).

From this marine capture fisheries perspective, '*systematic conservation planning*' (The realisation of conservation goals requires strategies for managing whole landscapes including areas allocated to both production and protection - sensu Margules and Pressey, 2000) must be heralded as a sustainable approach which is based upon the clear objective of supply side sustainability; namely helping to identify the locations and configuration of habitats (Giakoumi et al., 2015). For subsequent (EBFM) management (Margules and Pressey, 2000; Moilanen et al., 2009); such planning often materialises in the shape of marine reserves (Giakoumi et al., 2011) or designation of specific habitats for protection (Giakoumi et al., 2015).

In this chapter the management objective aligns to the protection of habitat as the primary supplier, and therefore the SSCM of supply side seafood security. This finds itself in line with intragovernmental legislation and the desired establishment of a series of protected areas; the Natura 2000 network in the marine environment.

"Where quantitative data on habitat areas are available, it would be possible to apply the arbitrary sufficiency levels 20-60% for non-priority habitats and >60% for priority habitats (e.g., Posidonia beds) as suggested in the 'Criteria for assessing national lists of pSCIs at the biogeographical level' (Hab. 97/2 rev. 4 18/11/97)."

European Topic Centre on Biological Diversity, 2014

It is therefore suggested that the minimum objective of the Lipsi stakeholders would be to conserve >60% of the distribution of *Posidonia oceanica* meadows in their coastal waters (the study area) and thus seek to address the threats (Figure 97) to the seafood supply chain highlighted in this thesis and other papers. Per European Union (EU) guidelines, this should be achieved within a management time frame of 20 years.

Historical data on the "original" distribution of seagrass meadows in the region is not available (Telesca et al, 2015) and therefore the current distribution of the seagrass meadows around Lipsi can be used as a baseline for future research and monitoring, and to support marine reserve designation (Giakoumi et al., 2011; Giakoumi et al., 2015). The figure of 60% has been proposed here in explicit recognition of the *Posidonia oceanica* seagrass habitat which has already been lost from Lipsi's coastal waters.

Figure 73. *Posidonia oceanica* seagrass meadows in the Mediterranean Sea. (a) Healthy meadow in the study region, (b) meadow impacted by fish farming, (c) meadow impacted by anchoring, and (d) meadow impacted by trawling. (Photos by Yiannis Issaris/www.yissaris.com).

5.5.3 Limitations and Future Research

As with any approach, the selection of mapping scale and detail represents a compromise between components (McKenzie et al., 2003), with 'time' and 'cost' key considerations in pursuing reliable TLEK (generated based on relationships of trust between researcher and TLEK holder), and the subsequent fishers' habitat map approach (Roelfsema and Phinn, 2010). In this study, the similarity amongst mind maps produced by the three fishers was deemed of acceptable accuracy for the task of creating a habitat typology and the generation of a broad scale habitat map. This is particularly important here because the further collection of data via this method was not achievable due field logistics and because of the availability of willing fishers at the time.

However, should more resources become available in the future, then further outreach to TLEK utilising similar methods with other fishers would be encouraged. Furthermore, if more detail was needed for data enrichment or to inform management decisions, then oceanographic surveys are a well-established technique (Blondel and Murton, 1997) which could be used in conjunction with SCUBA (available on Leros or Patmos) for deeper water benthic habitat verification (sensu Teixeria et al., 2013). For the scales of coastal and marine planning, the average margin of error (of up to 1600m found in FEK-derived maps) is relatively small (Blondel and Murton, 1997, Teixeira et al., 2013) and this error can reasonably be expected to be an order of magnitude smaller (~160m) based upon the errors of scale in equivalent studies (Teixeira et al., 2013). The application of this methodology (like TLEK) once again represents a compromise between mapping scale and detail, and once again should the opportunity arise for further implementation of these methods on Lipsi (which is both logistically possible and financially viable) they should be pursued. Especially since the detailed habitat maps produced by UAV represent just a fraction of the Lipsi coastal zone (Figure 80).

Of note in this chapter is that this is the first time that TLEK has been used to develop habitat maps in the Mediterranean Sea where it has been used to successful generate knowledge in a region that is known to be data poor – just 8% of coastline currently surveyed (see Telesca et al., 2015). It is also the first time (to my knowledge – see SeagrassWatch.org) that Seagrass-Watch protocol has been utilised in Greece. Finally, this chapter showcases the novel use of UAVs for ARS which has been shown here to provide accurate contextual data on habitat *size* and *distribution* for further site interrogation (via ISO of site habitat to establish habitat characteristics. The application of such an approach clearly opens new possibilities for coastal research and should act as a 'proof of concept' for application in further research. In fact, the combination of the novel capacity for high-resolution, low-altitude aerial photography (Ventura et al., 2016) and readily accessible citizen science methods for habitat assessment e.g. Mangrove-Watch, Seagrass-Watch, Coral-Watch (McKenzie et al., 2003) can provide communities with rapid assessment protocols for documenting spatial and biological change within coastal zones. For these reasons, remote sensing products can now be considered during the conceptual development of any ecological study.

CHAPTER 6 - Supply Chain Stage 2 - Assemblage

6.1 Introduction

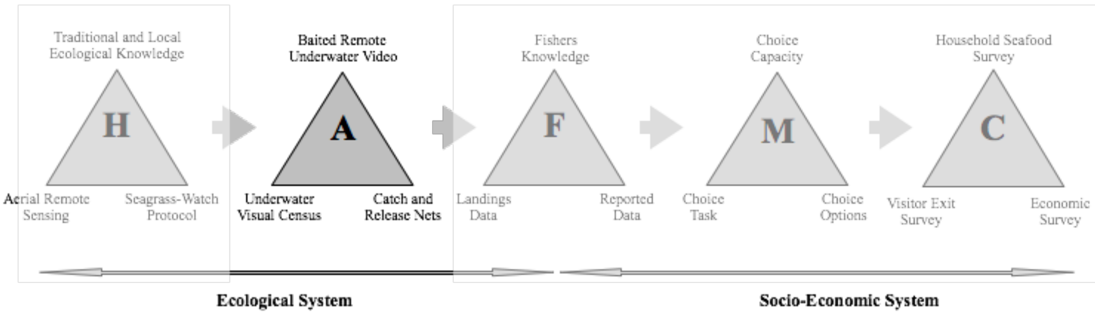


Figure 74. This chapter focuses on the Assemblage (A) as the second stage of the Small-Scale Capture Fishery supply chain. This supply chain stage is located within what would be conventionally conceptualised as the ecological system within the combined socio-ecological system.

The second stage of the Small-Scale Capture Fishery (SSCF) seafood supply chain (the species assemblage) can be envisaged as the productive fauna that is supported by and associated with specific habitats. This stage encompasses the early consumer elements of the marine food chain, or perhaps more accurately, the marine food web, of any given place. In practice, understanding both the productivity and health of a fishery requires a detailed understanding of the species interactions beyond simply 'what-eats-what'. In many respects, these food web complexities are reflected in the business and management literature by 'Supply Chain Network' theory. This theory offers a more complex representation of a supply chain structure, highlighting the levels of interdependence and connectivity within individual supply chain stages and the flow of information and materials across participating stakeholders and organisations (Lamming et al., 2000).

Early work on the changing nature of fisheries focussed on changes to the supply chain from a biological perspective; these early studies were conducted by authors such as Hjort (1914) who considered the *"Fluctuations in the great fisheries of northern Europe, viewed in the light of biological research*". As the century progressed scientific authors began to consider both the socio-economic and the ecological implications for fisheries as extractive industries, for example Gordon's

(1954) paper on "*The economic theory of a common-property resource: the fishery*" and Beverton and Holt's (1957) *"On the dynamics of exploited fish populations"* respectively.

More recently, whilst much work has been done on the decline in productivity of coastal fisheries e.g. Jackson et al, 2001; Worm et al., 2006; Halpern et al, 2008 much of the current thinking on food web changes linked to overfishing, unsustainable harvest, and the unintended ecosystem changes induced by widespread removal of marine species from high trophic levels, can be articulated through two complementary works: First, Pauly et al's (1998) 'fishing down' of marine food webs and second, Essington et al's, (2006) 'fishing through' of marine food webs. In both cases the marine environment is represented by the declining 'mean trophic level' of fisheries landings (essentially the change in the composition of the mean seafood product supplied by the fishery to the marketplace). 'Fishing down' refers to the sequential replacement of high-value upper-trophic-level species (e.g. Grouper) with less valuable lower-trophic-level species (e.g. Rabbitfish) as the former are depleted to economic extinction. 'Fishing through' refers to the sequential addition of lower-trophic-level fisheries to the extractive process within an ecosystem i.e. where fisheries for high-trophic-level species are maintained, and low-trophic level fisheries added, which results in a decline in the overall mean trophic level of landings (Pauly et al., 1998; Essington et al., 2006).

Supply Webs / Networks

From a Small-Scale Capture Fishery Sustainable Supply Chain Management perspective, the change of seafood product supply involves a need to understand more than just the linear set of exchange relationships in the supply chain (i.e. seafood products are extracted from the assemblage), but to understand food web relationships such as; if 'Product A - Groupers' is extracted, then how will that influence 'Product B - Lobsters'. Or, taken a step further, is the extraction of 'Product C - Urchins' likely to have a detrimental or positive effect on the capacity for 'Supplier A - Seagrass' to supply 'Product B – Lobsters' in the long-term? The need to understand the roles of species within food webs can be paralleled with the need to understand the relationships between diffuse networks of product suppliers (supply networks) in traditional supply chains. In both cases, the broad supply chain ‘stage’ represents an abridged picture of the complexities surrounding diffuse networks of product suppliers.

Prevailing marine fisheries management is (in theory!) based on fisheries biology, which derives largely from population biology and does not treat fish populations as components in their ecosystems (Pauly, 2009); this is despite recognition that the ecosystem effects of overfishing, including trophic cascades and loss of habitat-forming species, equal or exceed other human impacts on the sea (Jackson et al., 2001; Halpern et al., 2008; Worm et al, 2012).

Concurrently, many business management scholars have begun to study supply chain disruptions, and these studies have largely focused on assessing vulnerabilities that firms face and how to manage them (Ellis et al., 2010). In many cases, product supply disruptions (i.e., stoppages of product flows) do not originate from a focal firm’s facilities, but rather from its supply network (Kim et al., 2015). Such disruptions ‘within’ a stage, will not necessarily lead to supply chain disruptions ‘between stages’. However, if they do, then a firm’s failure to manage supply disruptions may have stemmed from a lack of understanding of the relationships within the wider supply network (Kim et al., 2015).

In the context of this SSCF conceptual framework, the species assemblage stage in the supply chain is determined by the supply network of habitats found within the focal (place) seascape. Therefore, an empirical understanding of what species exist within the seascape (*defining the seafood products*) and an understanding of what species come from which habitats (*establishing species-habitat associations*), in combination with establishing the tropic level of identified species, (*understanding food web relationships),* will empower SSCF SSCM decisions that can conserve or enhance the provision of seafood products linked to particular habitat types.

Species-Habitat Associations

In community ecology, an ‘association’ is a type of ecological community with a predictable species assemblage composition. The species assemblage is associated with a particular habitat with a consistent physiognomy (structural appearance). The use of such a system of classification helps facilitate communication among scientists. It facilitates the classification of the group of faunal species (the assemblage) which associate with a habitat, into a workable unit; making the concept *"a general-purpose biological classification of high predictive value"* (Stussey, 1997). Such association of species to habitats has been articulated as critical to the understanding of ecological data because of the effect that changing sampling scales has on our ability to detect ecological processes and relationships that occur within faunal communities (Thrush et al, 1998; Hewitt et al, 1998).

This has led to a proliferation of multi-scale research on habitat selection (see Mayor et al, 2009 for review), with the work of Moranta et al (2006) on *"Multi-scale spatial variability in fish assemblages associated with Posidonia oceanica meadows in the Western Mediterranean Sea"* of particular concern to this thesis. Moranta et al (2006) found that that *Posidonia oceanica* meadows from different locations in the western Mediterranean displayed a similar 'carrying capacity' (maximum population size) although large-scale hydrodynamic conditions and differences in meadow structure lead to differently 'shaped' fish communities (different species-habitat associations) at their different sites.

For example, the larger meadow complexity they found in Formentera likely favoured smaller sized fish, since small species and/or individuals were known to find more shelter and food there. In their study, the between-location scale (>100 km) is the most variable scale for species-specific densities, with spatial variability at the smallest scale (<1 km) also considerable. However, the variability corresponding to the intermediate scale (<10 km) was found to be non-significant (Moranta et al., 2006).

This chapter compliments the Species-Habitat Associations explored at a smaller habitat mediated scale e.g. Kaligirou et al (2010) at ≈120m^2, and Guidetti (2000) at ≈40m^2. Sale (1998) argued that our understanding of coral reef fish ecology would gain precision as the scales with 'real relevance' to reef fish are used in designing studies. However, reef fish species can occupy a home range anywhere between (Point Scale) a coral head (~30cm^2) to (Regional Scale) a reef network (several km^2). As such, the scale at which whole assemblage surveys are designed are a necessary compromise between species acting across multiple spatial scales.

Habitat-Guild Concept

The process of artificial community structuring can also be useful by further subdividing assemblages into 'guilds' of species that exploit the same resource in the same way. This is known as the habitat-guild concept (Simberloff and Dayan, 1991). Such a classification relates closely to the concept of 'trophic levels': the position an organism occupies in a food chain.

A 'guild' is a generic term that does not typically have strict, or even clearly defined boundaries; it may even have constituent 'guilds' embedded within it. What is important, is the concept of feeding guilds operating at particular 'trophic levels' e.g. groups of organisms that interact either as herbivores, omnivores or carnivores in a particular species assemblage (and thus food web). The trophic level is the position that an organism occupies in a food chain - what it eats, and what eats it.

A mean trophic level is calculated by assigning each fish or invertebrate species a number based on its own 'trophic level'. Trophic levels start at level 1 with primary producers, such as seagrass meadows, then moving through the primary consumers at level 2 (herbivores) that eat the primary producers to the secondary consumers at level 3 that eat the primary consumers (omnivories and carnivores) and so on. In marine environments, trophic levels range from two e.g. Rabbitfish (*Siganus luridus)* to four-five for apex predators like the Great White Shark (*Carcharodon carcharias)*. The mean trophic level can then be calculated for habitat mediated species assemblages by averaging the trophic levels for all the species reported from the habitat.

Understanding the mean trophic level of fish in a given assemblage has become an essential fisheries tool for measuring the health of marine ecosystems (Pauly et al, 1998; Pauly et al, 1995). In 2000, the Convention on Biological Diversity selected the mean trophic level of fisheries catch, renamed the "Marine Trophic Index," as one of eight indicators of ecosystem health (see Pauly and Watson (2005) for background and interpretation of the 'Marine Trophic Index').

Methods Section

Within this thesis, the proposed 'place' of study was chosen as Lipsi since it met the practical criteria of being a place of manageable scale (logistically). The choice of Lipsi as the 'place' of study, thus dictated the scale of the investigation, and the methods deployed.

The methods chosen herein are the ones considered most appropriate to interrogate the various seafood contributions of Lipsi's coastal habitats to the SSCF. Assemblage surveys were conducted at the patch scale, with the focus being on the faunal species-habitat associations to coastal habitat types, and specifically what guilds exist within these recorded assemblages.

This chapter generates two null hypotheses:

1. There is no significant difference in the species composition, species richness and abundance of fish in assemblages occurring over three different shallow inshore habitats, namely *Posidonia oceanica* seagrass meadows, rocky algal bottoms and un-vegetated sandy habitats.

2. Adults and small-sized specimens of some common inshore fish species exhibit no habitat preference (that would 'lend weight' to the Functional Guilds proposed by Kalogirou et al, 2010 site scale analysis).

6.2 Aims and Objectives

This chapter focuses on species assemblages associated to specific habitats. The aims of this chapter are to identify:

1. What species are present in the coastal zone around the island of Lipsi? (*define the seafood products)*
2. Which of the coastal habitats supply which of the species? (*association and connectivity)*

3. What are the age structures and trophic levels of the species that are present? (*food-web interactions*)

Objectives

1. To identify those seafood species [seafood products] present in the Lipsi coastal seascape via a triangulated approach (Underwater Visual Census, Baited Remote Underwater Video and Catch and Release Nets).
2. To identify which species associate with which habitat types (i.e. specific suppliers provide specific seafood products).
3. To establish quantitatively which habitats support the greater abundance, and the greater richness of species (i.e. variety and abundance of product supply).
4. To quantify adult to juvenile ratios within the coastal zone and to determine the mean trophic levels of the species assemblages recorded.

6.3 Materials and Methods

Triangulation in this chapter was achieved through the use of Underwater Visual Census (UVC), Baited Remote Underwater Video (BRUV) and the deployment of Catch and Release Net's (CRN) to record fish species diversity and abundance across habitat types. Adopting these multiple methods offers the most representative means of assessing assemblage composition by offsetting intrinsic bias (Colton and Swearer, 2010; Lowry et al, 2011 (Figure 99).

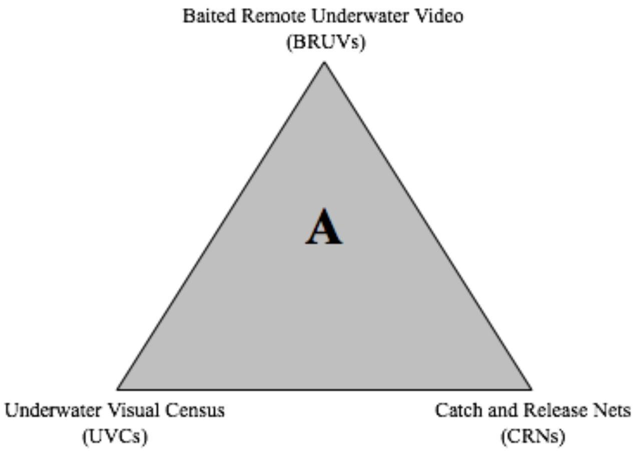


Figure 75. For a richer understanding of habitat mediated species assemblage, a triangulated approach incorporating Baited Remote Underwater Video (BRUV), Underwater Visual Census (UVC) and Catch and Release Nets (CRNs).

Study Sites

The nine sites described in Chapter 3 were chosen for assemblage surveys: (a) Vroulia, (b) Moschato, (c) Platis Gialos, (d) Kamares, (e) Chochlakoura (f) Limnh, (g) Papadria, (h) Kambos, and (i) Kimissi (Figure 100).

Habitat Typology

The habitat typology utilised for habitat comparison were those that were established by outreach to TLEK in Chapter 5; seagrass (*Posidonia oceanica*), rocky-algal and un-vegetated sandy bottom. No coralline algae habitats are present in the bays due to data being collected in the shallow (<10m) coastal zone.

Figure 76. Lipsi island is located in the northern Dodecanese archipelago, Greece (1:35,000 Scale) showing the location of the town (dark grey) and the nine bays considered in this study (a) Vroulia, (b) Moschato(c) Platis Gialos. (d) Kamares, (e) Chochlakoura, (f) Limnh (g) Papadria (h) Kambos and (i) Kimis

6.3.1 Underwater Visual Census

Underwater visual census (UVC) entails the *in-situ* identification of species, and enumeration of individuals in the underwater environment. UVC is one of the most widely adopted methods for surveying marine fish assemblages worldwide. For full details of the UVC protocol adopted in this thesis see the "Methods Appendix".

Apnea Point Counts

Apnea Point Count (APC) protocol invovled using snorkellers to record fish species, size and abundance in a visually estimated cylinder, with a radius of 4m (~50m^2) over a period of 10minutes. To minimize disturbance of surveyed fishes, snorkelers did their best to stay above the horizontal centre mark of the cylinder, rotating around the centre axis for a 360° survey (Figure 101).

Figure 77. A snorkeler / freediver conducting an Apnea Point Count

Apnea Belt Transects

Apnea Belt Transect (ABT) protocol involved establishing a 25m transect by using a 25m tape measure weighted to the substrate. The snorkeler locates the beginning of the first transect and conducts the 4m by 25m survey by swimming the length of the transect counting all fish sighted within the area 2m either side of the centre line (Figure 102).

Figure 78. A snorkeler / freediver conducting an Apnea Belt Transect

Size estimation

For both APC and ABT snorkelers recorded fish underwater, identifying to species level, and making abundance counts and size estimates in 5cm size categories (0-5cm, 5-10cm, 10-15cm etc.). Fish size was measured as Total Length (TL), which was estimated to the nearest centimetre. TL is defined as the length from the tip of the snout to the tip of the longer lobe of the caudal fin (Figure 103) and was deemed the most appropriate method for size estimation.

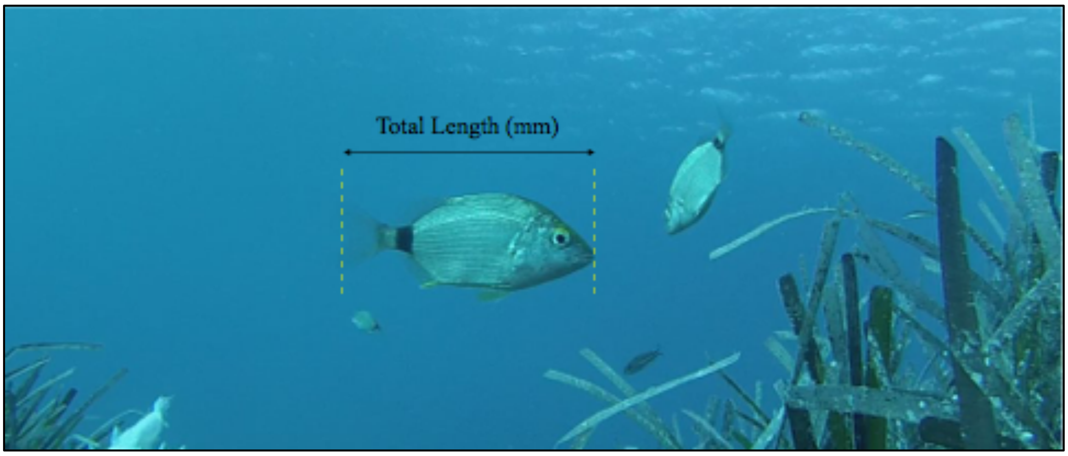


Figure 79. Total length of fish was estimated in 50mm (5cm) size categories.

Fish were defined as adults of the species if their TL was greater than the species Length at Maturity (Lm) e.g. a Dusky spinefoot (*Siganus* luridus) with a Lm at 14.2cm (FishBase 2016) would be an 'adult' in the 15-20cm size category. Lm refers to the length at which a given species can be considered can be fully mature or 'an adult'. Fish were recorded as 'juvenile' if their estimated TL was below the species Lm e.g. 5-10cm in this scenario, or as an 'intermediate' if the fish was estimated to be in the 5cm size category surrounding the species Lm e.g. 10-15cm in this scenario.

Operational Parameters

Transect parameters were chosen so that the surface area surveyed by 25m ABT (~100m^2) was approximately twice that surveyed by Point Count (~50m^2). Due to their large size, the ABT transects were split into five 20m^2 'segments' to help facilitate accuracy of counting and size estimates. During ABT standard-counts, all fishes present in the survey area were counted unless it was clear that they had been counted in a previous segment.

Figure 104 illustrates the differences between 'belt transects' and 'point counts' specifically regarding periods of diver apnea (breath-hold) and snorkeler / freediver recovery.

AIMS Standard Operational Procedure, Number 3

A visual census aims at recording an instantaneous estimate of abundance for the target species present within the bounds of the transect. Unfortunately this theoretical goal can never be realised due to factors such as the time taken to count and record each individual, and commonly, the inability to scan the entire transect area at any one time. Consequently there is a need to employ a sampling technique which best approximates this ideal.

Although it is impossible to census the entire transect in a given instant, it is possible to treat the transect as a series of instantaneous counts, such that each portion of the transect area is only viewed once for any given target species. In practice this is achieved by viewing ahead and counting target species in an area of the transect contained well within the bounds of visibility (often the next reinforcing rod serves as an appropriate break point). During the first scan of the section the most mobile target species should be counted and recorded, with progressively less mobile species recorded in consecutive counts. Fish entering the transect during, or after, that area of transect is sampled are not included as they were not present during the initial count. Once the most mobile species have been counted the observer moves along the centre of the transect searching for the more cryptic and slower moving target species, being careful to include individuals of the most mobile species which were obscured from view by the structure of the reef during the initial count of the area.

BOX 1. The Australian Institute of Marine Science Standard Operation Procedure Census Technique (Halford and Thompson, 1994)

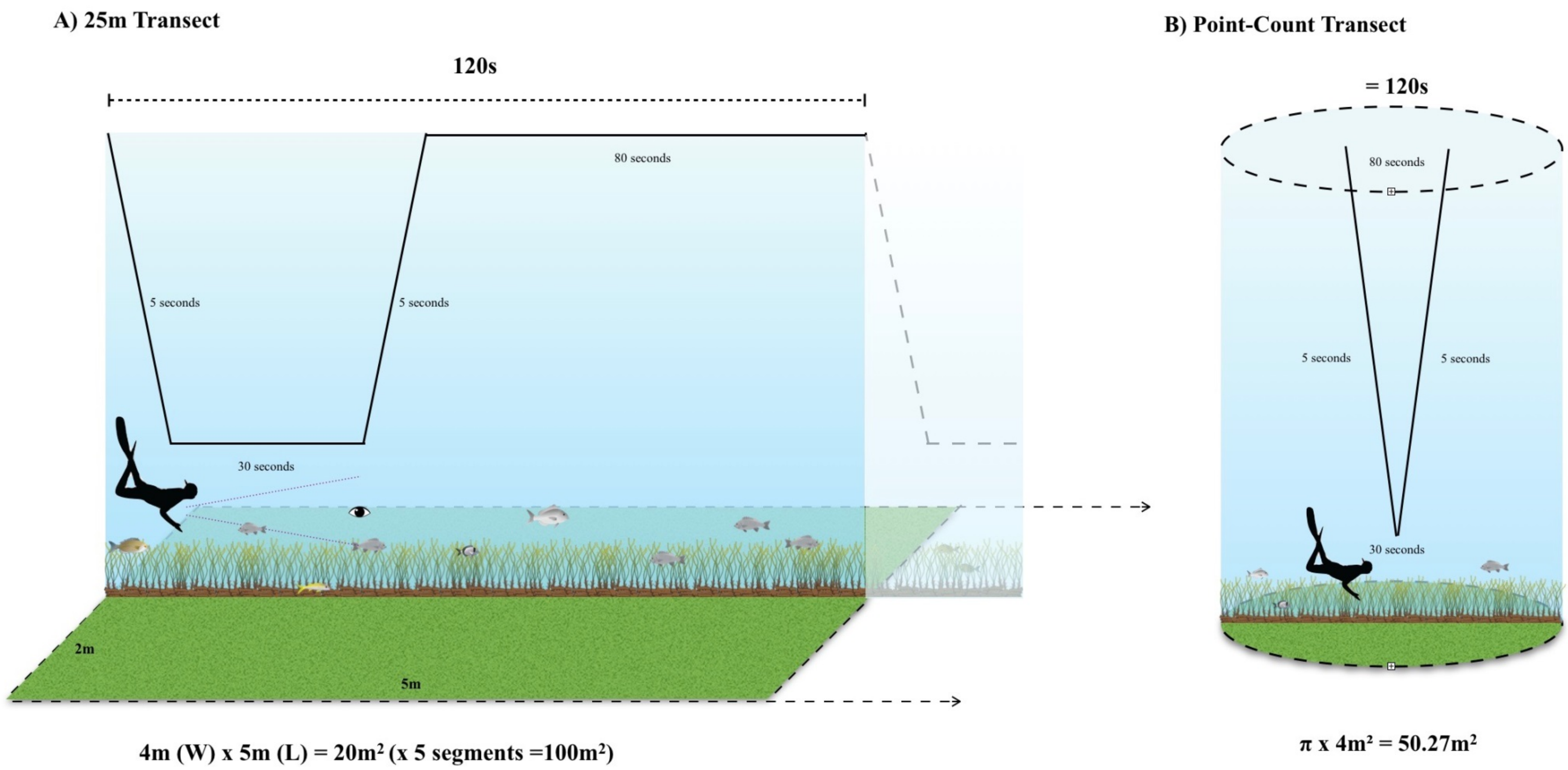


Figure 80. A) 25m Belt Transects were broken up into 5 x 20m^2 segment. B) Point-Counts covered an area of ~50m^2. In accordance with the freedivers 'rule of thumb', observers spent twice as long in recovery (80 seconds) than was spent at apnea (40 seconds) on each freedive.

6.3.2 Baited Remote Underwater Video

monoBRUV

Two monoBRUV systems were deployed twice daily between 9am and 5pm, once in the morning, once in the afternoon. 'Mono' refers to the use of a single GoPro™ camera deployed in GoPro™ waterproof housing (40m) with clear acrylic viewing ports. GoPro's offer affordable wide angle HD cameras (e.g. 1080p, 16:9, Medium FOV, 30fps). The GoPro's were attached to a platform and pointed horizontally (parallel to the ground) towards a bait box. Cameras were turned on and set to record before monoBRUV's were deployed, and were turned off after monoBRUV's were retrieved (Figure 105).

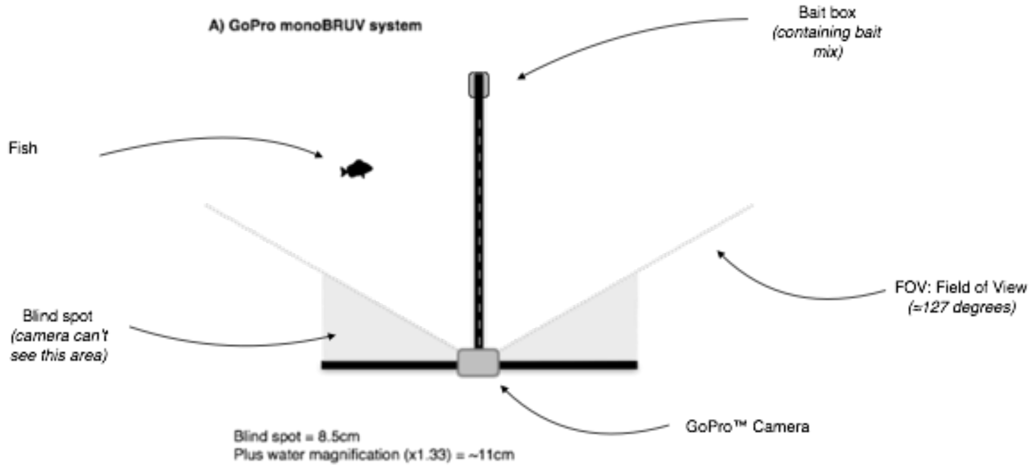


Figure 81. GoPros offer affordable wide angle HD cameras that can be used to make portable monoBRUVs. The camera is pointed towards a bait box and fish that swim into the FOV (Field of View) are recorded.

All monoBRUV deployments were carried out in <9m depth in one of the three specified habitat types (seagrass, rocky-algal, sandy bottom). The two monoBRUV systems were manually lowered to the seabed and visually inspected to ensure that the camera's field of view was both horizontal and unobstructed. Each monoBRUV system was then left for a minimum of 62 minutes to include a 2-minute settlement period and a 60-minute sampling period. To reduce field time two monoBRUV systems were used with both camera systems deployed simultaneously. The systems were buoyed at the surface, and deployed at least 25m from each other to prevent the crossing of bait plumes (Dunlop et al, 2015) (Figure 106).

Figure 82. Final GoPro monoBRUV design used in this study. The GoPro was attached to a plastic frame and directed towards a bait box located at the end of a pole. The frame was weighted with two 1kg dive weights to ensure stability on the seafloor. This design enabled a snorkeler to deploy the system by hand in water depths of <10m.

Video Data Processing

The 60 minutes of video generated from each monoBRUV deployment were reviewed in specialist BRUV analysis software called Event Measure, SeaGIS Pty Ltd (Figure 107). The relative abundance counts were obtained from 'Max_n': the maximum number of fish belonging to each species present in the Field of View (FOV) of the camera at one time (Priede et al. 1994). Some individuals could not be identified either because they were too far away, or were obscured in some way, these individuals were not recorded. For each video the species richness and abundance were recorded.

Figure 83. A single frame from the monoBRUV video as would be seen in SEAGIS Event Measure software. The Max_n for this frame is *Sarpa salpa* (n=35) and *Diplodus annularis* (n=1).

6.3.3 Capture and Release Nets

To support the conclusions drawn from UVC and BRUV data a total of five Capture and Release Nets (3 Fyke Nets, 2 Minnow Nets) were deployed twice daily (AM and PM) at each site with nets having a ‘soak time’ of approximately ~12hrs per deployment. This equates to 18 Fyke Net and 12 Minnow Net hauls per site and 162 Fyke Net and 108 Minnow Net hauls per season.)

Nets were deployed randomly across coastal habitat types (seagrass, rocky-algal, sandy bottom) over the three (Winter, Spring, Autumn) seasons. Nets were not deployed in Summer to prevent conflict with local tourism operations. These nets, whilst only capturing relatively few individuals per season, were deployed to:

a) Ensure that a precise quantitative data set on species size was subsequently available to relate to, and provide quality assurance for, the size estimates generated in UVC
b) Capture cryptic and/or nocturnal species that would not show up in either the UVC or BRUV data.

In addition, the nets were chosen as a means to record some of the juvenile fish (via smaller mesh sizes) that would unlikely be accurately recorded or picked up by the other methods. Two different styles of nets were used to try to offset any inherent bias associated with using just one type of net. The Minnow nets were baited (using the same recipe as the monoBRUV system) to attract fish into the net via the bait plume. Both nets are designed for ‘catch and release’ and are described in the Methods Appendix.

6.4 Data Analysis

Presentation

Several fish species recorded by UVC and BRUV are defined as pelagic species (see FishBase), and therefore by definition are not associated with any benthic habitat type (these species were recorded anyway since they may be utilising benthic habitats for foraging purposes). In addition, many of the species recorded, whilst contributing to biodiversity, do not directly contribute to the small-scale fishery supply chain. Finally, certain epi-benthic (species that live just above the seabed) species are known to aggregate, resulting in marked variations in density that can obscure patterns in data analysis (Ferrell and Bell, 1991; Guidetti 2000). Consequently, the data is presented including only Small Scale Capture Fishery (SSCF) associated species. On this basis the following groups/species were excluded from further analysis:

I. **Pelagic species (non-habitat associated):** Needlefish (Belonidae) Jacks/Pompanos (Carangidae) and Mackerels / Tunas (Scombridae)

II. **Very small species (non-fishery):** Gobies (Gobiidae), Combtooth blennies (Blennidae), Pipefish/Seahorses (Syngnathidae) and Threefin blennies (Tripterygiidae).

III. **Patchy distributions (gregarious planktivourous species):** *Centracanthus cirrus, Spicara maena, Spicara smaris, Chromis chromis, and Boops boops.*

Size data

For the UVC size data a distinction had to be made between juvenile, intermediate (if their length at maturity was known to fall within a 5cm size category i.e. Lm =12.7cm is in the 10cm-15cm size range) and adult fish abundances. Fish were classified using maturity data from FishBase (Froese and Pauly, 2016) when available or using the commonly applied ‘rule of thumb’ that individuals smaller than one-third of the maximum species’ length were juvenile (Nagelkerken & van der Velde 2002, Unsworth et al., 2008). For species with a maximum length >90 cm, individuals were recorded as juveniles when <30 cm long. All maximum length data were obtained from FishBase (Froese & Pauly 2016).

Abundance data

Whole species assemblage data was categorised into 1 of 3 groups of habitat association (seagrass, rocky-algal reef, sand). This simple categorisation was based on the habitats' typology as defined in Chapter 6. Data was also categorised into another 1 of 3 groups for season (spring, summer, autumn) and 1 of 8 groups for site; Moschato, the site of the ex-aquaculture facility, was removed from analysis because it was not representative of a typical site.

'Standard count' analysis refers to the traditional, simplest technique for analysing data collected from UVCs; identifying and recording each individual of a species during a transect. The primary benefit of standard-count technique is that the data generated represents the entire assemblage. The primary limitation is that there is a higher risk of double counting. Duplicate counts are of particular concern in stationary point counts since fish may re-enter the survey area numerous times. To reduce this error, the Max_n technique was developed for BRUV stations. 'Max_n' refers to the maximum number of fish belonging to each species present in the Field of View (FOV) of the camera at one time (Priede et al. 1994) whilst for 'standard counts' human observers try to track individuals that leave and re-enter their survey cylinder or belt. UVC data has been analysed by standard count and BRUV data by Max_n. CRN data have provided supplementary data to support size analysis.

Summary statistics were calculated including means ±SE. ANOSIM and SIMPER were performed on root transformed data. ANOSIM is a distribution-free method of multivariate data analysis primarily employed to compare the variation in species abundance and composition among sampling units and SIMPER provides a similarity percentage analysis for identifying which species contribute more to the explained variance. ANOSIM was used to analyse any differences in fish abundance and species richness between different habitats with SIMPER identifying the principal species responsible. ANOSIM results are presented with the *p*-value (significance levels) and R-value (the strength of the factors on the samples). SIMPER results are presented as Top 5 contributors.

Analysis of differences in reported fish assemblage structure between habitat type was conducted using multi-variate non-metric multidimensional scaling ordination (MDS) and Bray-Curtis cluster analysis using the computer package PRIMER 7 (Clarke & Gorley 2015). The Bray-Curtis similarity index was applied on square-root transformed data (to down-weigh the influence of rare and extremely abundant species) and to generate a rank similarity matrix, which was then converted into an MDS ordination. To check on the adequacy of the low-dimensional approximations seen in cluster and MDS the use of PRIMER 7 enabled clusters to be superimposed upon the MDS ordination (Clarke & Gorley 2015). ANOSIM was used to investigate the differences identified from MDS and CLUSTER (Clarke & Gorley 2015).

6.5 Results

This results section comprises three sections relating to;

1. Underwater Visual Census (Apnea Point Counts and 25m Apnea Belt Transects)
2. Baited Remote Underwater Video
3. Capture and Release Netting (Fyke and Minnow nets)

For both UVC and CRN general descriptive data is presented for the combined methods (e.g. APC and ABT, Fyke and Minnow). Data analysis, where applicable is presented for each method. Total survey effort for all three methods is presented in Table 20.

The total 'in-water' time of 72hrs for both APC and ABT is calculated from 432 repeats of 10min surveys (108 per season; (9 sites, 12 repeats per site) Equally the total 'in-water' time of 432hrs for BRUV reflects the 432 individual 1hr BRUV deployments (108 per season; (9 sites, 12 repeats per site). The 5,832hrs for Fyke nets represents 486 deployments over 3 seasons (no deployments in summer). 3 Fykes were deployed at each site twice each day (AM and PM) for three days (18 deployments per site). 9 sites were surveyed each season (n=162) over 3 seasons (n=486). Fyke nets were left in the water for ~12hrs = 5,832hrs. The 3,888hrs for Minnow nets represents the same survey effort over the same seasons except using only 2 minnow nets. Together the three methods provide a robust analysis of species assemblage composition.

Table 7. Total survey effort from UVC, monoBRUV and CRN triangulation. NB – Fyke and Minnow nets were unable to be deployed in summer due to tourist activities.

Methods	Technique	Deployments (n)	Seasons	In-Water Time (hrs)
Underwater Visual Census	Apnea Point Count	432	Wi, Sp, Su, Au	72hrs
	Apnea Belt Transect	432	Wi, Sp, Su, Au	72hrs
Baited Remote Underwater Video	monoBRUVs	432	Wi, Sp, Su, Au	432hrs
Catch & Release Nets	Fyke nets	486	Wi, Sp, Au	5,832hrs
	Minnow nets	324	Wi, Sp, Au	3,888hrs

6.5.1. Underwater Visual Census

General description of fish assemblages from Underwater Visual Census

Over four seasons a total of 15,980 individuals (from 78 species, 28 families) were recorded by a combined 864 Underwater Visual Censuses (432 APCs, 432 ABTs) equating to 144hrs (8,640 minutes) of in water UVC surveys. *Posidonia oceanica* seagrass was targeted for UVC 412 times (APC 209, ABT 203), Rocky-Algal habitat 185 times (APC 98, ABT 87), and sandy substrate 267 times (APC 125, ABT 142). Atherinidae, Mugilidae, Mullidae and Sphyraenidae were combined into family categories due to the difficulty of species identification from direct visual observation in the field (Guidetti, 2000). Sixty-three species were recorded by APC and seventy-four species by ABT. Four species were unique to APC and fifteen were unique to ABT. The remaining sixty species were recorded by both methods but these results highlight the value of a multimethod approach. Table 21 represents the species assemblage identified by UVC methods during the study.

Table 8. Species assemblage identified by Underwater Visual Census during the study. Grey highlights species of importance to Small-Scale Capture Fishery.

Apogon imberbis	*Symphodus cinereus*	*Siganus luridus*
Atherinidae sp.	*Symphodus doderleini*	*Siganus rivulatus*
Belone belone	*Symphodus mediterraneus*	*Boops boops*
Parablennius rouxi	*Symphodus melanocercus*	*Spicara maena*
Parablennius sanguinolentus	*Symphodus ocellatus*	*Spicara smaris*
Parablennius tentacularis	*Symphodus roissali*	*Dentex dentex*
Arnoglossus laterna	*Symphodus rostratus*	*Diplodus annularis*
Arnoglossus thori	*Symphodus tinca*	*Diplodus sargus sargus*
Bothus podas	*Pteragogus pelycus*	*Diplodus vulgaris*
Pseudocaranx dentex	*Thalassoma pavo*	*Lithognathus mormyrus*
Seriola dumerelli	*Xyrichtys novacula*	*Oblada melanura*
Trachinotus ovatus	*Stephanolepis diaspros*	*Sarpa salpa*
Dasyatis pastinaca	Muglidae sp.	*Sparus aurata*
Gobius auratus	Mullidae sp.	*Spondyliosoma cantharus*
Gobius bucchichi	*Muraena helena*	Sphyraenidae sp.
Gobius cobitis	*Chromis chromis*	*Syngnathus typhle*
Gobius couchi	*Umbrina cirrosa*	*Synodus saurus*
Gobius fallax	*Sparisoma cretense*	*Echiichthys vipera*
Gobius geniporus	*Scorpaena maderensis*	*Trachinus draco*
Gobius niger	*Scorpaena notata*	*Trachinus radiatus*
Gobius paganellus	*Scorpaena porcus*	*Tripterygion delaisi*
Gobius vittatus	*Epinephelus costae*	*Tripterygion melanurus*
Thorogobius ephippiatus	*Epinephelus marginatus*	*Tripterygion tripteronotum*
Coris julis	*Serranus cabrilla*	*Uranoscopus scaber*
Labrus merula	*Serranus hepatus*	*Octopus vulgaris*
Labrus viridis	*Serranus scriba*	*Sepia officinalis*

Whole species assemblages

For whole species assemblages (all the species identified in a given habitat), the total number of species (total cumulative species richness) was highest in seagrass (67), second highest in rocky-algal (60) and lowest (48) over bare sand habitats (Table 22a). Fifty species were in common to both seagrass and rocky-algal habitats, whilst the overlap in species between three habitats was just thirty-eight (Table 22a).

Small-Scale Capture Fishery associated species assemblage

Once the numerical contributions of the non-Small-Scale Capture Fishery species (see 7.4) had been removed from the whole species assemblage a similar picture was observed, with species richness highest in seagrass (32), second in rocky-algal (29) and lowest on sand (23) (Table 22b). Seven species were common to both seagrass and rocky-algal habitats, whilst the overlap in species between all three habitats was just eighteen (5b).

Table 9. Number of species recorded by Underwater Visual Census (combined Apnea Belt Transect & Apnea Point Count) in each of the three habitats for (a) whole species assemblages (b) small scale capture fishery related species. Dashed lines link total species found in Rocky-Algal habit with Seagrass and Sand habitats. Solid lines link Seagrass and Sand habitats.

	Habitat		
Type of species	**Seagrass**	**Rocky-algal**	**Sand**
(a)			
Unique species	12	7	6
Total species	67	60	48
Shared between two habitats	50	40	38
Shared among three habitats		38	
Total number of species		78	
(b)			
Unique species	3	2	3
Total species	32	29	23
Shared between two habitats	7	2	0
Shared among three habitats		18	
Total number of species		32	

General description of variations in life-history of species present

Of the 15,980 individuals identified by UVC, 7385 individuals (46.2%) from 32 species could be defined as habitat associated fishery species (e.g. non-pelagic, non-planktivourous and non-fishery). Of these thirty-two species, 82.9% of individuals were juveniles, 13.5% were intermediate (5cm size category ca. Lm) and just 3.6 % were adults. Once the very rare fishery species were excluded (i.e. < 5 individuals/year) there were 20 species remaining (n= 7307). These 20 species represented 98.9% of the fishery associated species assemblage found in the <9m depth zone. The relative life-history figures remain broadly similar to the 32 species; 83.4% of SSCF associated species were juveniles of the species, 13.2% were intermediate, and just 3.4% were adults. The relative life-history stages for these 20 fishery species are presented in Figure 108.

Size data also revealed that the shallow coastal zone acts as a nursery area for intermediate and young adults of the rare and highly prized (high-value) species (see Chapter 9) of Common dentex (*Dentex dentex*) (Juvenile (J): 0, Intermediate (I) : 1, Adult (A): 1), Gilthead seabream (*Sparus* aurata) (J:51, I:8, A:5), Golden grouper (*Epinephelus costae*) (J:3, I:0, A:0), Dusky Grouper *(Epinephelus margniatus*) (J:3, I:0, A:0) and Shi Drum *(Umbrina cirrosa*) (J:1, I:0, A:0) as well as high trophic level predators such as the Mediterranean moray (*Muraena 201elena*) (J:2, I:0, A:0). Life-history data also revealed that aside from being a valuable nursery habitat for the SSCF, there are many other small species that inhabit the shallow coastal zone throughout their entire lives. These species are from several families including; Atherinidae (< 5 species) Apogonidae (1 species), Blennidae (3 species), Bothidae (3 species), Gobiidae (10 species), Labridae (11 species), Pomacentridae (1 species), Serranidae (1 species), Tripterygiidae (3 species). Whilst these species do not directly contribute to the SSCF supply chain as seafood ‘products’, they are part of the food web that ensures the stability of seafood supply from these coastal habitats. Namely, it is the abundance of these smaller species that act as prey for species of higher trophic levels (Kalogirou et al, 2010). In the following sections, the life-history parameters (size and age) of the assemblage is first explored by UVC and subsequently from the CRN data. Statistical analysis covers diversity and abundance of individuals recorded in each habitat type. Data analysis is conducted for each of the two UVC methods (APC and ABT) individually.

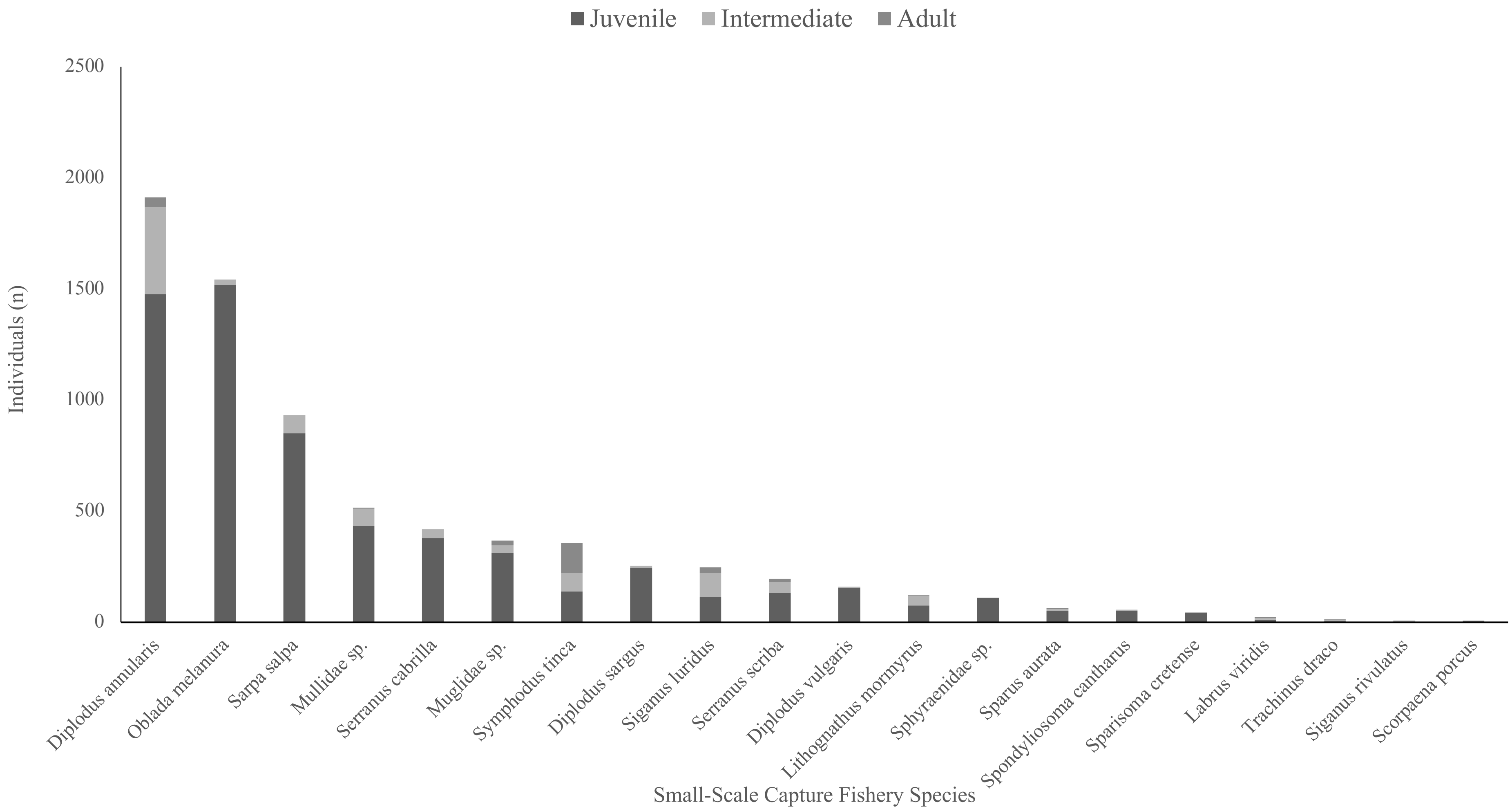


Figure 84. Relative proportion (Juvenile, Intermediate, Adult) of the 20 Small-Scale Capture Fishery species as estimated by combined. Underwater Visual Census (combined Apnea Belt Transect and Apnea Point Count size data). Species are presented in order of abundance.

Apnea Point Count (APC)

General description of species diversity

APC data is presented in relation to a $50m^2$ survey area. Of the sixty-three species recorded, the five most most abundant fishery species recorded across habitats and seasons by APC were *Diplodus annularis* (2.15 ±4.11 fish / $50m^{-2}$), *Oblada melanura* (1.67 ±3.75 fish / $50m^{-2}$), *Sarpa salpa* (1.38 ±6.47 fish / $50m^{-2}$) *Serranus cabrialla* (0.46 ±0.91 fish / $50m^{-2}$) and Muglidae sp. (0.42 ±2.15 fish $50m^{-2}$). The rank Top 10 fishery species observed by APC are presented in Table 23.

The Sparidae were the most abundant fish family of the fishery species. Many rare species were reported, with abundances of less than 0.01 fish / $50m^{-2}$ (23 species in total). By whole assemblage, a mean number of 17.71 ±21.70 fish / $50m^{-2}$ were found with mean species richness 3.98 ±2.81 per APC. By small-scale fishery species, a mean number of 8.26 ±12.54 fish / $50m^{-2}$ were found with a mean species richness of 2.01 ±1.90 per APC.APC showed mean fishery species abundance to be ≈ 6.5 times greater in seagrass (12.59 ±11.67 fish / $50m^{-2}$), and ≈ 5 times greater in rocky-algal (9.75 ±6.88 fish / $50m^{-2}$), than on bare sand (1.95± 2.57 fish / $50m^{-2}$), species richness was also higher in seagrass 2.71 ±1.80, in comparison to 2.67±1.44 for rocky-algal habitat and 0.72 ±0.73 for sand. Many species (Table 21; above) were recorded as present only in one habitat type by APC, for example the Brown Wrasse (*Labrus merula*) was only recorded in seagrass whilst the Golden grouper (*Epinephelus costae*) and Dusky grouper (*Epinephelus marginatus*) were only recorded in rocky-algal habitat. Of those fishery species, omnipresent across habitats, 9 species had a higher abundance in seagrass (*Symphodus tinca,* Mullidae, *Serranus cabrilla; Serranus scriba, Siganus luridus, Diplodus annularis, Oblada melanura, Sparus aurata, Spondyliosoma cantharus*) whilst 3 had a higher abundance in rocky-algal habitats (*Sparisoma cretense, Diplodus vulgaris, Sarpa salpa*) and 2 had higher abundances on sand (*Lithognathus mormyrus,* Muglidae). The most abundant species from the whole assemblage sampled by APC was the Mediterraenan Rainbow Wrasse (*Corus julis*) which had higher abundances both on seagrass (3.93 ±2.62) and rocky-algal (3.01 ± 2.01) habitats.

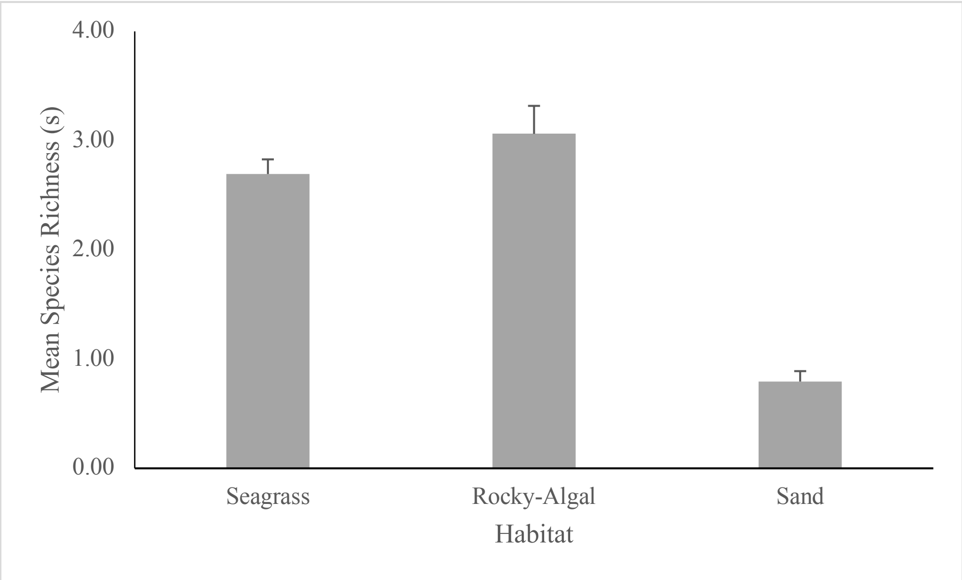
Table 10. Mean relative abundance (±SE) of the Rank Top 10 Small-Scale Capture Fishery species observed by Apnea Point Count across all four seasons at Lipsi, Dodecanese, Greece, per habitat type. Highlighted in grey are the highest mean abundance for each habitat type for each season/year.

Rank	Total Year (n)	Species	Winter (Dec-Jan-Feb)			Spring (Mar-Apr-May)			Summer (Jun-Jul-Aug)			Autumn (Sep-Oct-Nov)			Year (2014)			
			P	R	S	P	R	S	P	R	S	P	R	S	P	R	S	ALL
1	927	*Diplodus annularis*	2.53 (±2.94)	0.40 (±0.45)	0.15 (±0.49)	2.90 (±2.89)	1.68 (±1.19)	0.60 (±1.59)	7.62 (±5.84)	0.88 (±0.88)	0.19 (±0.44)	3.92 (±3.55)	1.41 (±1.01)	0.00 (±0.00)	4.60 (±2.92)	1.04 (±0.92)	0.24 (±0.86)	**2.15 (±4.12)**
2	720	*Oblada melanura*	0.09 (±0.19)	0.00 (±0.00)	0.00 (±0.00)	1.06 (±1.67)	0.79 (±0.75)	0.10 (±0.19)	8.71 (±9.40)	0.96 (±1.06)	0.14 (±0.40)	2.75 (±4.60)	1.32 (±1.53)	0.00 (±0.00)	3.79 (±3.75)	0.84 (±1.06)	0.06 (±0.22)	**1.67 (±5.61)**
3	598	*Sarpa salpa*	0.56 (±0.73)	0.36 (±0.44)	0.03 (±0.10)	0.55 (±2.23)	6.63 (±6.43)	0.50 (±1.92)	2.38 (±4.89)	1.81 (±1.98)	0.14 (±0.35)	0.78 (±2.13)	1.68 (±2.70)	0.00 (±0.00)	1.42 (±3.19)	3.32 (±4.40)	0.16 (±0.98)	**1.38 (±6.49)**
4	199	*Serranus cabrilla*	0.58 (±0.72)	1.08 (±0.65)	0.10 (±0.23)	0.73 (±0.70)	0.63 (±0.37)	0.13 (±0.21)	0.42 (±0.54)	1.12 (0.87)	0.24 (±0.34)	0.47 (±0.77)	0.36 (±0.59)	0.03 (±0.10)	0.54 (±0.48)	0.84 (±0.65)	0.13 (±0.24)	**0.46 (±0.91)**
5	181	Mugilidae sp.	0.00 (±0.00)	0.00 (±0.00)	0.15 (±0.49)	0.00 (±0.00)	1.21 (±1.37)	0.05 (±0.14)	0.71 (±2.01)	1.08 (±1.94)	1.08 (1.81)	0.37 (±1.83)	0.41 (±0.87)	0.63 (±1.30)	0.24 (±0.77)	0.65 (±1.26)	0.46 (±1.15)	**0.42 (±2.15)**
6	152	Mullidae sp.	0.16 (±0.34)	0.00 (±0.00)	0.03 (±0.10)	0.00 (±0.00)	0.05 (±0.10)	0.03 (0.10)	1.38 (±2.30)	0.35 (0.44)	1.24 (±1.90)	0.25 (±0.59)	0.27 (±0.33)	0.17 (±0.36)	0.43 (±0.84)	0.17 (±0.28)	0.36 (±0.98)	**0.35 (±1.57)**
7	148	*Diplodus sargus*	0.37 (±1.03)	0.72 (±1.13)	0.03 (±0.10)	0.18 (±0.46)	1.00 (±0.84)	0.13 (±0.29)	0.91 (±1.41)	1.19 (±0.81)	0.08 (±0.21)	0.02 (±0.10)	0.18 (±0.30)	0.00 (±0.00)	0.35 (±0.64)	0.78 (±0.83)	0.06 (±0.19)	**0.34 (±1.22)**
8	142	*Symphodus tinca*	0.56 (±0.73)	0.36 (±0.44)	0.03 (±0.10)	0.16 (±0.30)	0.11 (±0.19)	0.03 (±0.10)	1.04 (±1.10)	0.42 (±0.41)	0.11 (±0.23)	0.65 (±0.90)	0.09 (±0.14)	0.00 (±0.00)	0.62 (±0.59)	0.26 (±0.32)	0.04 (±0.14)	**0.33 (±0.87)**
9	119	*Siganus luridus*	0.21 (±0.44)	0.08 (±0.19)	0.00 (±0.00)	0.20 (±0.60)	1.68 (±2.89)	0.00 (±0.00)	0.60 (±0.83)	0.15 (±0.23)	0.03 (±0.10)	0.67 (±1.49)	0.00 (±0.00)	0.00 (±0.00)	0.49 (±0.58)	0.41 (±1.45)	0.01 (±0.05)	**0.28 (±1.72)**
10	108	*Serranus scriba*	0.12 (±0.25)	0.28 (±0.32)	0.00 (±0.00)	0.14 (±0.25)	0.32 (0.36)	0.00 (0.00)	0.64 (±0.71)	0.38 (±0.46)	0.19 (±0.37)	0.47 (±0.62)	0.59 (±0.58)	0.00 (±0.00)	0.37 (±0.36)	0.39 (±0.44)	0.05 (±0.19)	**0.25 (±0.67)**

Diversity of species by habitat

APC data revealed mean species richness to be higher in both Rocky-Algal habitat (3.06 ±0.26) and Seagrass (2.69 ±0.13) and lower in Sand (0.79 ±0.36), APC data also revealed mean species abundance to be high in Seagrass (12.40 ±1.11) and Rocky-Algal habitats (11.38 ±1.60) whilst being much lower in Sand (5.64 ±1.30). Mean species richness and mean species abundance are presented in Figure 109.

a)



b)

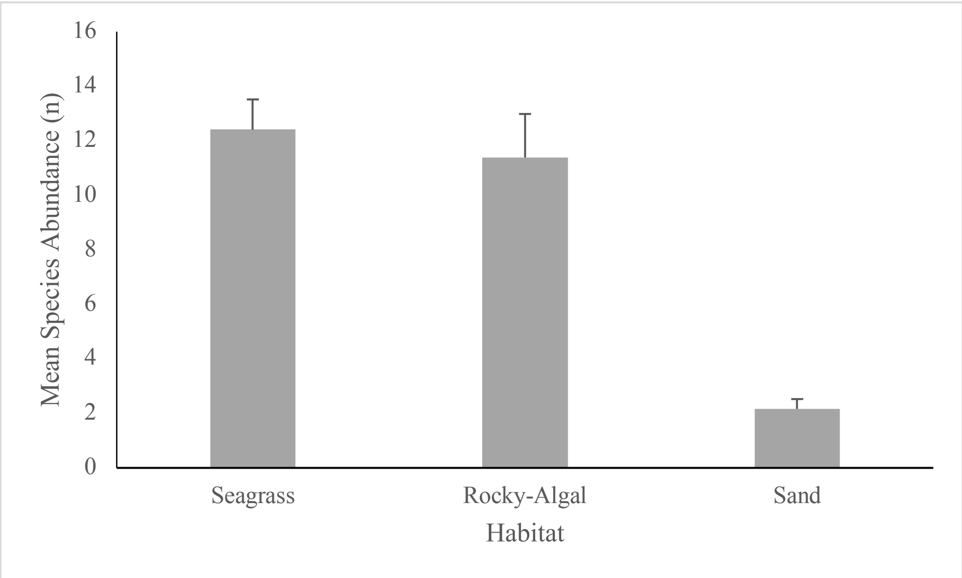


Figure 85. a) Mean species richness and b) mean species abundance (per 50m^2 survey area) for each of the three habitat types as recorded by Apnea Point Count methods.

Non-metric Multidimensional Scaling

Superimposed Bray-Curtis clusters onto nMDS ordination showed differentiation between assemblages by habitat (Figure 110). Seagrass and Rocky-Algal samples are scattered around a clustered group of sand showing seagrass fish assemblages to be more variable in these more complex habitats. Three-Way ANOSIM revealed significant differences between habitats (across seasons and sites (Average R = 0.251, $p > 0.001$)). These differences were greatest between Rocky-Algal and Sand habitats (R = 0.420, $p = 0.001$) and Seagrass and Sand habitats (R = 0.215, $p = 0.001$) and lowest, between Seagrass and Rocky-Algal habitats (R = 0.202, $p = 0.002$).

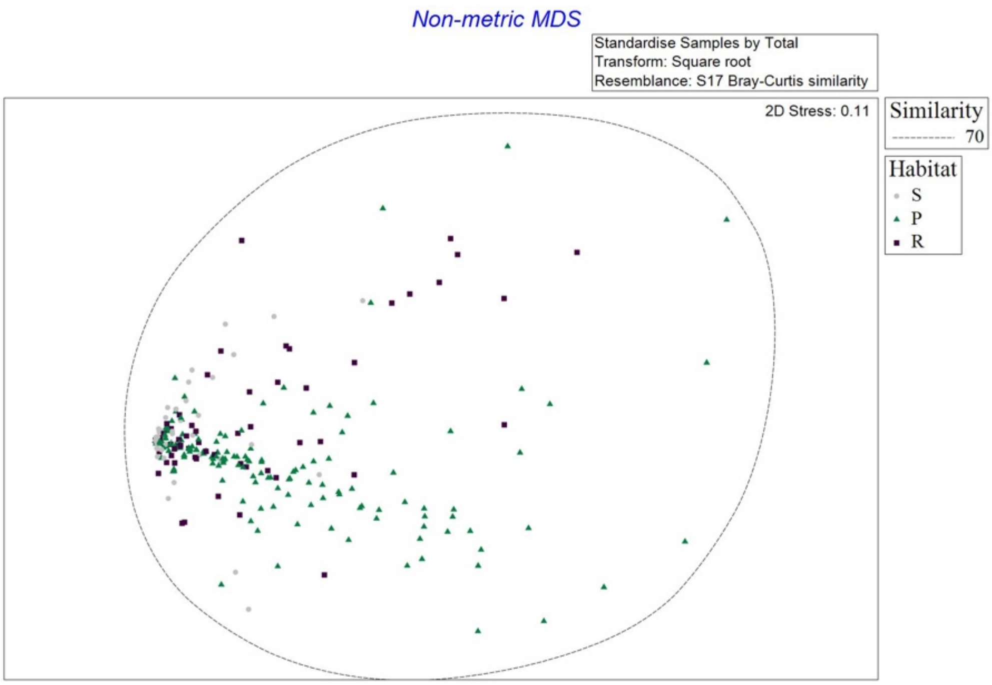


Figure 86. nMDS configuration with superimposed Bray-Curtis similarity clusters at the 70% level for sample comparison of fish assemblages as established by Apnea Point Count methodology.

Similarity Percentages

One-way SIMPER analysis revealed those species principally responsible for determining group similarities for Habitat (Table 24). Group similarities are presented for the highest contributing species with a cut-off percentage of 25.0%.

Table 11. The highest assemblage similarities for each habitat and the relative contributions of the highest contributing species for Apnea Point Count data.

Species	Mean Abundance	Mean Similarity	±StDev Similarity	Contribution %	Cumulative %
			Seagrass - Average similarity: 88.21		
Diplodus annularis	3.13	4.83	2.50	5.47	5.47
Oblada melanura	2.57	3.81	2.64	4.32	9.79
Serranus cabrilla	1.96	3.31	5.23	3.76	13.54
Symphodus tinca	1.92	3.27	5.70	3.71	17.25
Serranus scriba	1.84	3.21	6.65	3.64	20.89
			Rocky-Algal - Average similarity: 88.28		
Diplodus annularis	2.34	3.75	3.70	4.25	4.25
Sarpa salpa	2.56	3.66	2.41	4.15	8.39
Diplodus sargus	2.13	3.49	4.98	3.96	12.35
Serranus cabrilla	2.05	3.47	5.63	3.93	16.27
Oblada melanura	2.14	3.38	4.10	3.83	20.11
			Sand - Average similarity: 96.00		
Mullidae sp.	2.01	3.49	11.84	3.64	3.64
Mugilidae sp.	2.05	3.49	9.17	3.64	7.27
Lithognathus mormyrus	1.97	3.47	12.46	3.61	10.89
Diplodus annularis	1.95	3.46	14.93	3.61	14.49
Serranus cabrilla	1.92	3.46	15.00	3.60	18.10

SIMPER revealed noticeable divisions in the relative contributions of seafood species between habitat types, with three of the top five species contributing to both Seagrass and Rocky-Algal assemblages. In Sand habitat, however, principal contributions were made by species of Mullidae, Mugilidae and the Sand steenbrass (*Lithognathus mormyrus*).

Apnea Belt Transect (ABT)

General description of species diversity

Of the seventy-four species recorded the five most most abundant fishery species recorded across habitats and seasons by ABT were the *Diplodus annularis* (2.28 ±4.07 fish / 100m^{-2}), *Oblada melanura* (1.91 ±5.90 fish / 100m^{-2}), Mullidae sp. (0.84 ±3.22 fish / 100m^{-2}), *Sarpa salpa* (0.78 ±3.54 fish / 100m^{-2}), and *Serranus cabrilla* (0.51±0.98 fish / 100m^{-2}), (Table 25). The Seabreams (Sparidae) were the most abundant fish family of the fishery species. Many rare species were reported, with abundances of less than 0.01 fish / 100m^{-2} (31 species in total). By whole assemblage, a mean number of 19.28 ±19.76 fish / 100m^{-2} were found with a mean species richness 4.40 ±3.00 per ABT. By focal fishery species, a mean number of 8.37 ±12.13 fish / 100m^{-2} were found with a mean species richness of 1.99 ±1.94 per ABT. The rank Top 10 fishery species observed by ABT are presented in Table 25.

ABT showed mean fishery species abundance to be ≈4.2 times greater in seagrass (11.55 ±10.98 fish / 100m^{-2}), and ≈3.7 times greater in rocky-algal (10.16 ±6.93 fish / 100m^{-2}), than on bare sand (2.72± 3.79 fish / 100m^{-2}). In contrast to APC, ABT revealed higher species richness in rocky-algal habitat 2.84 ±1.55, in comparison to 2.48±1.71 in seagrass habitat, but both were again higher than 0.78 ±0.79 for bare sand. Many species (Table 21; above) were recorded as present only in one habitat type by ABT, for example the Brown Wrasse (*Labrus merula*), Green Wrasse (*Labrus* viridis), Shi Drum (*Umbrina* cirrosa) and Barracuda (Sphyraenidae sp.) were only recorded in seagrass whilst the Cardinalfish (*Apogon imberbis*) was only recorded in rocky-algal habitat. Of those fishery species present across all habitats, nine species had a higher abundance in seagrass (*Symphodus tinca, Serranus cabrilla; Serranus scriba, Siganus luridus, Diplodus annularis, Oblada melanura, Sparus aurata, Spondyliosoma cantharus,* Sphyraenidae, *Octopus vulgaris*) whilst 3 had a higher abundance in rocky-algal habitats (Muglidae*, Diplodus vulgaris, Diplodus sargus*) and 2 had higher abundances on sand (*Lithognathus mormyrus,* Mullidae). The most abundant species from the whole assemblage sampled by ABT was the Mediterraenan Rainbow Wrasse (*Corus julis*) which had higher abundances both on seagrass (5.33±4.61) and rocky-algal (3.98 ± 2.56) habitats.

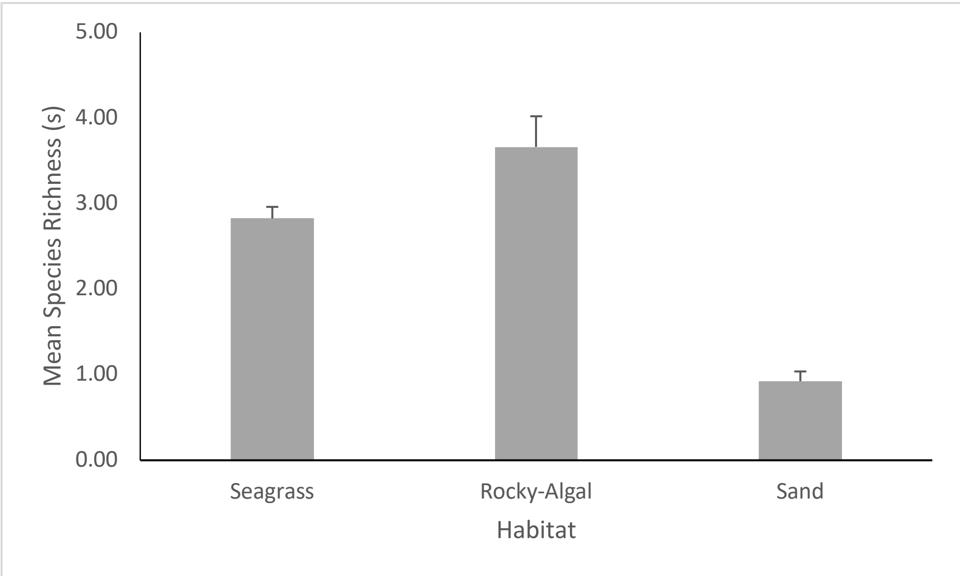
Table 12. The mean relative abundance (±SE) of the Rank Top 10 focal fishery species observed by Apnea Belt Transect across all four seasons at Lipsi, Dodecanese, Greece, per habitat type. Highlighted in grey are the highest mean abundance for each habitat type for each season/year.

Rank	Total Year (n)	Species	Winter (Dec-Jan-Feb)			Spring (Mar-Apr-May)			Summer (Jun-Jul-Aug)			Autumn (Sep-Oct-Nov)			Year (2014)			
			P	R	S	P	R	S	P	R	S	P	R	S	P	R	S	ALL
1	985	*Diplodus annularis*	1.57 (±1.81)	0.43 (±0.52)	0.09 (±0.22)	2.44 (±2.20)	0.85 (±0.89)	0.09 (±0.29)	6.27 (±4.99)	3.29 (±2.09)	1.84 (±2.34)	4.74 (±4.79)	0.33 (±0.27)	0.33 (±0.88)	3.95 (±2.86)	1.43 (±1.21)	0.54 (±1.27)	**2.28 (±4.07)**
2	824	*Oblada melanura*	1.06 (±1.93)	0.05 (±0.10)	0.00 (±0.00)	0.84 (±1.54)	0.40 (±0.51)	0.00 (±0.00)	8.06 (±9.85)	2.64 (±2.92)	0.68 (±0.79)	3.92 (±4.57)	0.44 (±0.47)	0.00 (±0.00)	3.64 (±3.92)	1.05 (±1.52)	0.15 (±0.40)	**1.91 (±5.90)**
3	363	Mullidae	0.27 (±0.99)	0.00 (±0.00)	0.06 (±0.14)	0.00 (±0.00)	0.00 (±0.00)	0.03 (±0.10)	2.29 (±3.26)	3.46 (±3.09)	3.71 (±4.44)	0.02 (±0.10)	0.56 (0.57)	0.28 (0.58)	0.60 (±0.48)	1.23 (±1.61)	0.91 (±2.27)	**0.84 (±3.22)**
4	336	*Sarpa salpa*	0.84 (±2.81)	2.00 (±2.55)	0.00 (±0.00)	0.00 (±0.00)	2.70 (±4.04)	0.00 (±0.00)	1.86 (±3.20)	1.79 (±2.31)	0.00 (±0.00)	0.36 (±1.04)	1.78 (±2.00)	0.00 (±0.00)	0.79 (±1.57)	2.05 (±2.82)	0.00 (±0.00)	**0.78 (±3.54)**
5	221	*Serranus cabrilla*	0.80 (±0.80)	0.81 (±0.53)	0.09 (±0.17)	0.88 (±0.70)	0.50 (±0.35)	0.11 (±0.23	0.80 (±1.01)	0.54 (±0.59)	0.19 (±0.30)	0.48 (±0.70)	1.00 (±0.77)	0.08 (±0.17)	0.70 (±0.60)	0.69 (±0.58)	0.11 (±0.22)	**0.51 (±0.98)**
6	213	*Symphodus tinca*	0.63 (±1.03)	0.14 (±0.17)	0.29 (±0.45)	0.31 (±0.54)	0.15 (±0.17)	0.11 (±0.30)	1.10 (±1.55)	1.39 (±1.16)	0.16 (±0.35)	0.86 (±1.30)	0.33 (±0.33)	0.00 (±0.00)	0.70 (±0.84)	0.59 (±0.63)	0.13 (±0.32)	**0.49 (±1.33)**
7	187	Muglidae	0.02 (±0.10)	0.14 (±0.29)	0.06 (±0.19)	0.94 (±2.14)	0.35 (±0.67)	0.23 (±0.77)	0.27 (±0.75)	2.14 (±2.16)	0.84 (±1.02)	0.00 (±0.00)	0.61 (±0.82)	0.50 (±1.83	0.21 (±0.64)	0.93 (±1.23)	0.44 (±1.16)	**0.43 (±2.00)**
8	129	*Siganus luridus*	0.04 (±0.19)	0.29 (±0.58)	0.00 (±0.00)	0.00 (±0.00)	0.10 (0.14)	0.00 (±0.00)	0.86 (±2.21)	0.46 (±0.51)	0.10 (±0.29)	0.96 (±1.79)	0.44 (±0.40)	0.00 (±0.00)	0.49 (±1.00)	0.33 (±0.44)	0.02 (±0.14)	**0.30 (±1.47)**
9	112	Sphyraenidae	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	1.88 (±4.84)	0.71 (±1.92)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.46 (±1.73)	0.23 (±0.96)	0.00 (±0.00)	**0.26 (±2.62)**
10	106	*Diplodus sargus*	0.16 (±0.53)	0.48 (±0.71)	0.00 (±0.00)	0.06 (±0.14)	0.40 (±0.40)	0.00 (±0.00)	0.20 (±0.52)	1.11 (±0.96)	0.03 (±0.10)	0.16 (±0.52)	1.56 (±1.14)	0.00 (±0.00)	0.14 (±0.32)	0.89 (±0.85)	0.01 (±0.05)	**0.25 (±0.95)**

Diversity of species by habitat

ABT data revealed mean species richness to be high in both Rocky-Algal habitat (3.66 ±0.36) and Seagrass (2.83 ±0.13) and low in Sand (0.92 ±0.11), ABT data also revealed mean species abundance to be high in both Rocky-Algal (13.17 ±1.89) and Seagrass habitats (12.53 ±1.02) whilst being much lower in Sand (3.12 ±0.57). Mean species richness and mean species abundance are presented in Figure 111.

a)



b)

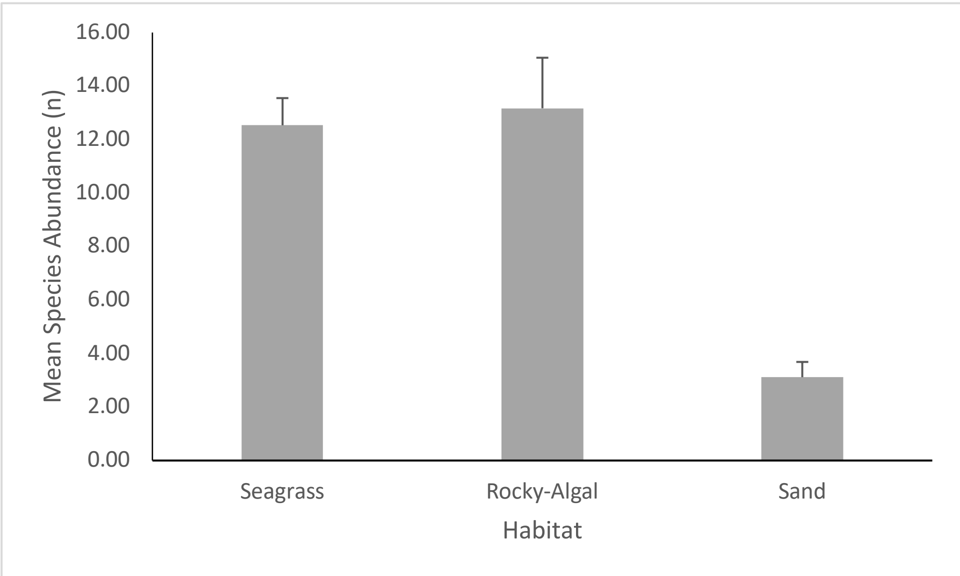


Figure 87. a) Mean species richness and b) mean species abundance (per $100m^2$ survey area) for each of the three habitat types as recorded by Apnea Belt Transect methods.

Non-metric Multidimensional Scaling

Superimposed Bray-Curtis clusters onto nMDS ordination showed differentiation between assemblages. These differences are presented for Season, Habitat, Site and Mosaic (Figure 112). Seagrass and Rocky-Algal samples are scattered around a more clustered grouping of sand, showing seagrass and rocky-algal fish assemblages to be more variable in these more complex habitats.

Three-Way ANOSIM revealed significant differences between habitats (across seasons and sites (Average R = 0.192, $p > 0.001$). These differences were greatest between Rocky-Algal and Sand habitats (R = 0.353, $p = 0.002$) and Seagrass and Sand habitats (R = 0.219, $p = 0.001$) and lowest, between Seagrass and Rocky-Algal habitats (R = 0.146, $p = 0.008$).

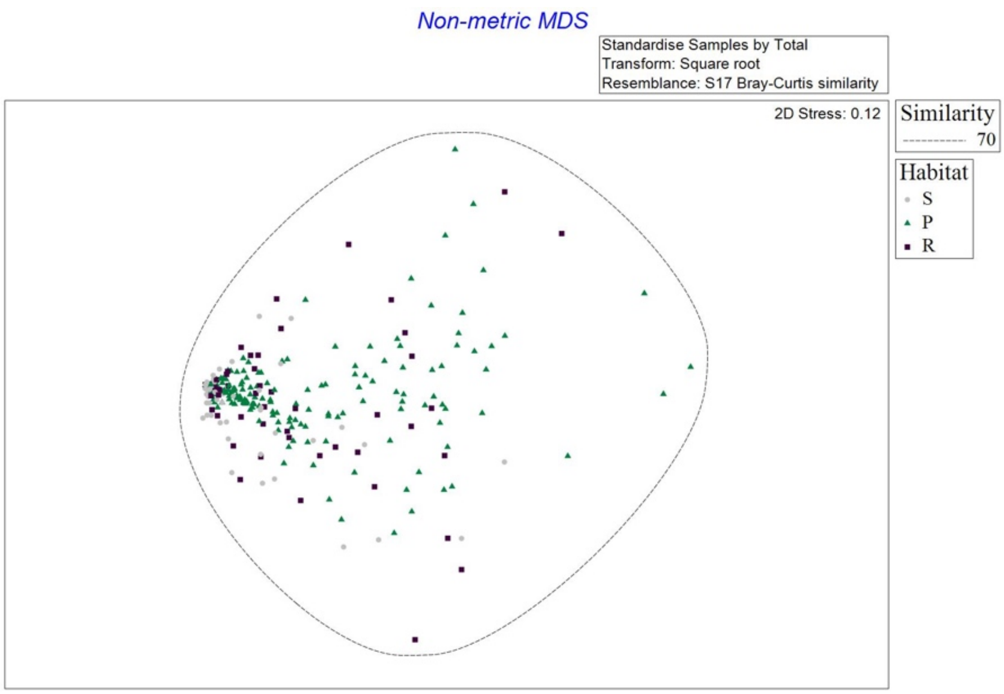


Figure 88. nMDS configuration with superimposed Bray-Curtis similarity clusters at the 70% level for sample comparison of fish assemblages as established by Apnea Belt Transect methodology, over four seasons, and eight sites, around Lipsi island, Greece.

Similarity Percentages

One-way SIMPER analysis revealed those species principally responsible for determining group similarities for Habitat. Group similarities are presented for the highest contributing species with a cut-off percentage of 25.0%. The Top 5 species per habitat are presented in Table 26.

Table 13. Highest assemblage similarities for each habitat and the relative contributions of the highest contributing species. ***L.mormyrus = Lithognathus mormyrus***

Species	Mean Abundance	Mean Similarity	±StDev Similarity	Contribution %	Cumulative %
		Seagrass - Average similarity: 89.17			
Diplodus annularis	2.95	4.28	2.74	4.80	4.80
Oblada melanura	2.50	3.41	2.50	3.83	8.63
Serranus cabrilla	1.93	3.03	5.00	3.39	12.02
Symphodus tinca	1.86	2.91	5.56	3.26	15.28
Serranus scriba	1.70	2.86	8.12	3.20	18.49
		Rocky-Algal - Average similarity: 88.12			
Diplodus annularis	2.35	3.47	3.36	3.94	3.94
Sarpa salpa	2.27	3.10	3.00	3.52	7.45
Diplodus sargus	1.99	3.04	4.88	3.45	10.91
Serranus cabrilla	2.04	3.04	4.45	3.45	14.36
Oblada melanura	1.92	3.01	4.73	3.42	17.78
		Sand - Average similarity: 95.36			
Mullidae sp.	2.02	3.15	7.85	3.30	3.30
Mugilidae sp.	1.92	3.06	8.92	3.21	6.51
L. mormyrus	1.89	3.05	10.18	3.19	9.71
Diplodus annularis	1.78	3.03	16.31	3.18	12.89
Serranus cabrilla	1.90	3.03	9.56	3.18	16.07

SIMPER revealed noticeable divisions in the relative contributions of seafood species between habitat types. This was most marked in Sand habitats, whose principal contributions were again made by the by the species of Mullidae, Mugilidae and the Sand steenbrass (*Lithognathus mormyrus*).

6.5.2 Baited Remote Underwater Video

General description of species diversity

Over four seasons a total of 13,614 individuals (from 66 species, 28 families) were recorded by 432, 60 minute, monoBRUV deployments equating to 432hrs (25,920 minutes) of underwater video footage. *Posidonia oceanica* seagrass was targeted for monoBRUV 209 times, Rocky-Algal habitat 98 times, and sandy substrate 125 times. Atherinidae, Mugilidae, Mullidae and Sphyraenidae were combined into family categories due to the difficulty of species determination by a direct visual observation (Guidetti, 2000). The total number of species (total species richness) was highest in seagrass (57), second highest in rocky-algal (47) and lowest (43) over bare sand habitats (Table 27a). Thirty-eight species were in common to both seagrass and rocky-algal habitats, forty between seagrass and sand, and thirty-four between rocky-algal and sand (Table 27a). Once the numerical contributions of the non SSCF species had been removed a similar picture was observed (Table 27b).

Table 14. Number of species recorded by Baited Remote Underwater Video in each of the three habitats for (a) whole species assemblages (b) small scale capture fishery related species. Dashed lines link total species found in Rocky-Algal habit with Seagrass and Sand habitats. Solid lines link Seagrass and Sand habitats.

	Habitat		
Type of species	**Seagrass**	**Rocky-algal**	**Sand**
(a)			
Unique species	11	6	3
Total species	58	47	44
Shared between two habitats	38	40	34
Shared among three habitats		33	
Total number of species		66	
(b)			
Unique species	6	2	1
Total species	29	24	20
Shared between two habitats	21	19	19
Shared among three habitats		19	
Total number of species		33	

Notably 88% (29/33) of SSCF related species were recorded in *Posidonia oceanica* seagrass meadows. Table 28 represents the whole species assemblage (all 66 species) identified by BRUV methods during the study.

Table 15. Species assemblage identified by Baited Remote Underwater Video during the study. Grey highlights species of importance to the Small-Scale Capture Fishery.

Apogon imberbis	*Symphodus mediterraneus*	*Serranus scriba*
Atherinidae sp.	*Symphodus melanocercus*	*Siganus luridus*
Belone belone	*Symphodus ocellatus*	*Siganus rivulatus*
Parablennius gattorugine	*Symphodus roissali*	*Boops boops*
Parablennius incognitus	*Symphodus rostratus*	*Spicara maena*
Parablennius tentacularis	*Symphodus tinca*	*Spicara smaris*
Arnoglossus laterna	*Pteragogus pelycus*	*Dentex dentex*
Arnoglossus thori	*Thalassoma pavo*	*Dentex gibbosus*
Bothus podas	*Xyrichtys novacula*	*Diplodus annularis*
Pseudocaranx dentex	*Stephanolepis diaspros*	*Diplodus sargus sargus*
Seriola dumerelli	*Dicentrarchus labrax*	*Diplodus vulgaris*
Trachinotus ovatus	Muglidae sp.	*Lithognathus mormyrus*
Fistularia commersonii	Mullidae sp.	*Oblada melanura*
Gobius auratus	*Muraena helena*	*Sarpa salpa*
Gobius bucchichi	*Chromis chromis*	*Sparus aurata*
Gobius cobitis	*Sparisoma cretense*	*Spondyliosoma cantharus*
Gobius fallax	*Sciaena umbra*	Sphyraenidae sp.
Gobius geniporus	*Euthynnus alletteratus*	*Synodus saurus*
Coris julis	*Scorpaena scrofa*	*Trachinus radiatus*
Labrus viridis	*Epinephelus costae*	*Tripterygion delaisi*
Symphodus cinereus	*Epinephelus marginatus*	*Octopus vulgaris*
Symphodus doderleini	*Serranus cabrilla*	*Sepia officinalis*

Variations in number of species present

Of the sixty-six species recorded, the five most abundant fishery species recorded across habitats and seasons by APC were the Muglidae (4.46 ±10.94 fish/deployment), *Diplodus annularis* (3.53 ±4.51 fish/deployment), *Sarpa salpa* (2.39 ±7.25 fish/deployment), *Oblada melanura* (2.01 ±3.62 fish/deployment), and *Diplodus sargus* (1.81±2.82 fish/deployment). (Table 29). The Seabreams (Sparidae) were the most abundant fish family of the fishery species. Many rare species were reported, with abundances of less than 0.01 fish/deployment (25 species in total). By (a) whole assemblage, a mean number of 31.51 ±24.10 fish/deployment were found with a mean species richness 8.50 ±4.01 per monoBRUV deployment, by (b) focal fishery species, a mean number of 21.47 ±18.56 fish/deployment were found with a mean species richness of 5.53 ±2.86 per perm monoBRUV deployment. The rank Top 10 fishery species observed by monoBRUV are presented in Table 29.

MonoBRUV showed mean fishery species abundance to be ≈1.7 times greater in seagrass (21.05 ±14.47 fish/deployment), and ≈2.8 times greater in rocky-algal (34.03 ±18.63 fish/deployment), than on bare sand (12.34± 8.55 fish/deployment). MonoBRUV revealed species richness to be highest in rocky-algal (6.60 ± 3.10 species) and seagrass (6.30 ± 3.62 species) habitats, both of which were higher than bare sand (3.40 ±1.88 species). Many species (Table 28; above) were recorded as present only in one habitat type by monoBRUV, for example the Green Wrasse (*Labrus viridis*), Brown meagre (*Sciaena umbra*) and Cuttlefish (*Sepia officinalis*) were only recorded in seagrass whilst the Cardinalfish (*Apogon imberbis*), the Golden grouper (*Epinephelus costae*) and Dusky grouper (*Epinephelus marginatus*) were only recorded in rocky-algal habitat.

Of those fishery species, omnipresent across habitats, 10 species had a higher abundance in seagrass (*Symphodus tinca, Serranus cabrilla; Serranus scriba, Siganus luridus, Diplodus annularis, Diplodus sargus, Oblada melanura, Sarpa salpa, Sparus aurata, Spondyliosoma cantharus* and Sphyraenidae) whilst 4 had a higher abundance in rocky-algal habitats (Muglidae sp. Mullidae sp. *Sparisoma cretense, Diplodus vulgaris,*) and 1 had higher abundances on sand (*Lithognathus mormyrus*). The most abundant family of species from the whole assemblage sampled by monoBRUV were the Muglidae sp.

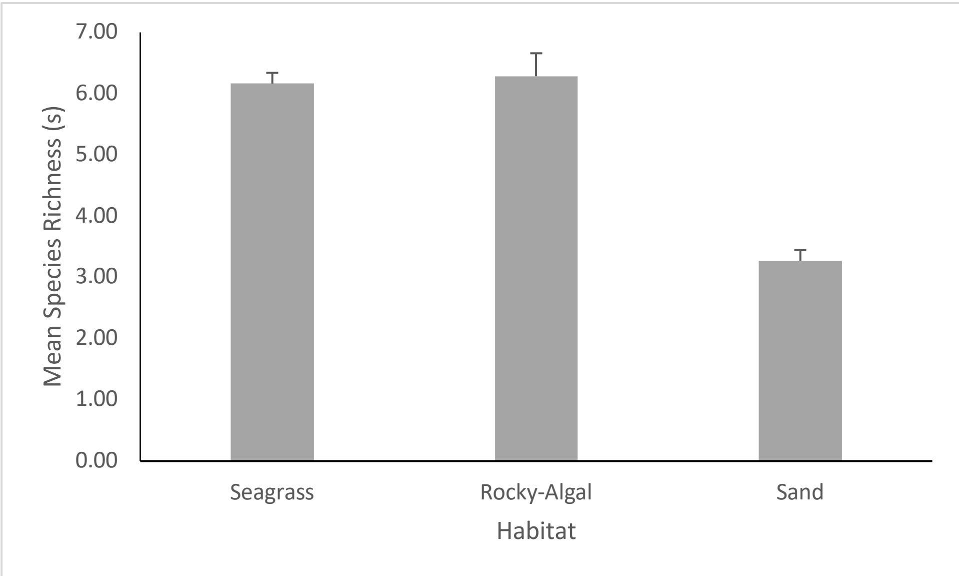
Table 16. The mean relative abundance (±SE) of the Rank Top 10 focal fishery species observed by monoBRUV across all four seasons at Lipsi, Dodecanese, Greece, per habitat type. Highlighted in grey are the highest mean abundance for each habitat type for each season/year.

Rank	Total Year (n)	Species	Winter (Dec-Jan-Feb)			Spring (Mar-Apr-May)			Summer (Jun-Jul-Aug)			Autumn (Sep-Oct-Nov)			Year (2014)			
			P	R	S	P	R	S	P	R	S	P	R	S	P	R	S	ALL
1	1925	Mugilidae sp.	1.12 (±2.19)	3.04 (±2.72)	1.29 (±1.41)	1.23 (±1.91)	6.18 (±4.86)	1.66 (±1.68)	1.95 (±3.85)	21.13 (±13.46)	7.69 (±8.63)	1.51 (±2.29)	16.92 (±13.37)	5.03 (±3.82)	1.49 (±3.62)	11.71 (±18.34)	3.78 (±8.51)	**4.46 (±10.94)**
2	1527	*Diplodus annularis*	3.54 (±2.85)	4.00 (±3.15)	0.93 (±1.11)	4.94 (±2.94)	0.64 (±0.82)	0.32 (±0.57)	7.04 (±4.41)	2.13 (±2.07)	1.69 (±1.85)	6.42 (±4.68)	5.00 (±4.47)	0.37 (±1.06)	5.33 (±3.50)	3.04 (±5.65)	0.78 (±2.21)	**3.53 (±4.51)**
3	1034	*Sarpa salpa*	1.19 (±2.31)	3.63 (±4.67)	0.36 (±0.68)	1.29 (±2.19)	2.32 (±1.92)	0.58 (±1.75)	2.93 (±4.42)	6.79 (±7.26)	1.34 (±1.49)	4.06 (±8.43)	5.96 (±6.17)	0.07 (±0.19)	2.47 (±6.70)	4.70 (±10.56)	0.58 (±2.20)	**2.39 (±7.25)**
4	867	*Oblada melanura*	0.42 (±0.74)	1.26 (±1.05)	0.14 (±0.23)	1.58 (±1.94)	1.59 (±1.26)	0.89 (±1.10)	5.91 (±5.08)	3.88 (±2.49)	3.07 (±2.44)	2.02 (±2.88)	1.80 (±1.43)	0.07 (±0.19)	2.55 (±4.33)	2.11 (±2.96)	1.03 (±2.42)	**2.01 (±3.62)**
5	783	*Diplodus sargus*	0.81 (±1.32)	1.56 (±1.32)	0.46 (±0.56)	1.17 (±1.76)	3.73 (±2.12)	1.42 (±1.51)	2.38 (±2.33)	5.33 (±3.02)	2.69 (±1.89)	1.23 (±2.06)	1.36 (±1.06)	1.93 (±1.63)	1.47 (±2.32)	2.92 (±3.47)	1.62 (±2.43)	**1.81 (±2.82)**
6	724	*Siganus luridus*	0.75 (±1.13)	1.78 (±2.16)	0.14 (±0.23)	1.21 (±2.19)	0.95 (±0.74)	0.05 (±0.19)	3.16 (±3.16)	5.08 (±3.40)	0.28 (±0.68)	3.70 (±4.07)	1.60 (±1.23)	0.23 (±0.67)	2.21 (±3.72)	2.36 (±4.04)	0.17 (±0.92)	**1.68 (±3.48)**
7	380	*Sparus aurata*	0.54 (±0.57)	0.81 (±0.65)	0.64 (±0.61)	0.52 (±0.61)	0.91 (±0.60)	1.03 (±0.78)	1.18 (±1.06)	0.83 (±0.55)	1.10 (±0.79)	0.87 (±0.79)	0.48 (±0.42)	1.77 (±1.18)	0.80 (±0.98)	0.76 (±0.97)	1.14 (±1.30)	**0.88 (±1.10)**
8	362	*Symphodus tinca*	1.48 (±3.02)	0.56 (±0.46)	0.04 (±0.10)	1.50 (±1.35)	0.68 (±0.46)	0.18 (±0.37)	0.85 (±0.93)	0.63 (±0.46)	0.17 (±0.25)	1.85 (±3.01)	0.36 (±0.36)	0.00 (±0.00)	1.39 (±2.82)	0.55 (±0.79)	0.10 (±0.42)	**0.84 (±2.29)**
9	338	Mullidae sp.	0.35 (±1.37)	7.88 (±11.38)	0.07 (±0.14)	0.15 (±0.37)	0.14 (±0.21)	0.26 (±0.40)	0.47 (±0.68)	0.75 (±0.90)	0.52 (±0.74)	0.32 (±0.44)	0.28 (±0.37)	0.33 (±0.62)	0.35 (±0.99)	2.40 (±11.87)	0.30 (±0.95)	**0.79 (±5.76)**
10	310	*Lithognathus mormyrus*	0.38 (±1.07)	0.63 (±0.70)	1.25 (±1.32)	0.31 (±0.70)	0.05 (±0.10)	1.53 (±1.57)	0.60 (±0.83)	0.08 (±0.19)	0.86 (±0.91)	0.26 (±0.61)	0.00 (±0.00)	2.93 (±2.19)	0.42 (±1.04)	0.20 (±0.76)	1.65 (±2.59)	**0.72 (±1.75)**

Diversity of species by habitat

BRUV data revealed mean species richness to be high in both Rocky-Algal habitat (6.28 ±0.38) and Seagrass (6.16 ±0.18) and lower in Sand (3.27 ±0.17), BRUV data also revealed mean species abundance to be highest in Rocky-Algal (32.42 ±3.12) and Seagrass habitats (20.66 ±0.99) whilst being much lower in Sand (11.62 ±1.09). Mean species richness and mean species abundance are presented in Figure 113.

a)



b)

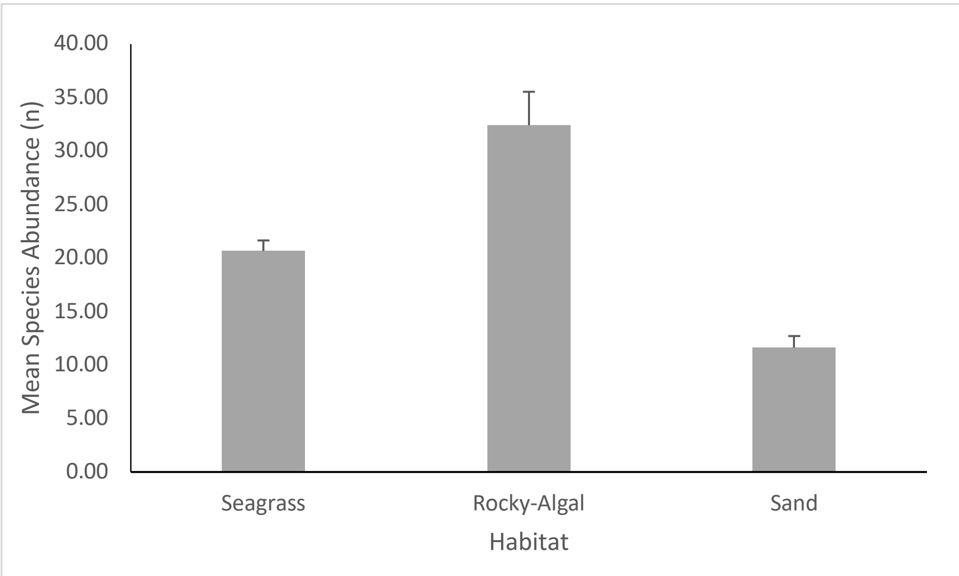


Figure 89. a) Mean species richness and b) mean species abundance for each of the three habitat types as recorded by monoBRUV methods.

Non-metric Multidimensional Scaling

Superimposed Bray-Curtis clusters onto nMDS ordination showed differentiation between assemblages. These differences are presented for Season, Habitat, Site and Mosaic (Figure 114). Seagrass and Rocky-Algal samples are scattered in two-dimensions around a more clustered grouping of sand in one dimension, this shows seagrass and rocky-algal fish assemblages to be more variable.

Three-Way ANOSIM revealed significant differences between habitats (across seasons and sites (Average R = 0.332, $p > 0.001$). These differences were greatest between Rocky-Algal and Sand habitats (R = 0.562, $p = 0.001$) and Seagrass and Rocky-Algal habitats (R = 0.378, $p = 0.001$) and lowest, between Seagrass and Sand habitats (R = 0.220, $p = 0.001$).

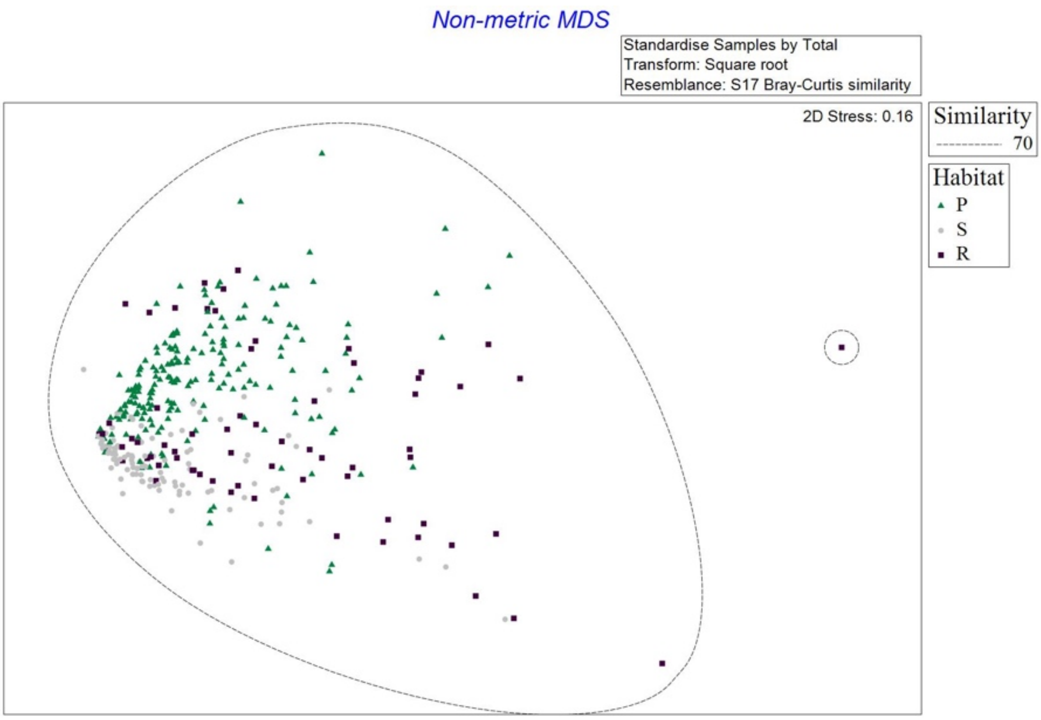


Figure 90. nMDS configuration with superimposed Bray-Curtis similarity clusters at the 70% level for sample comparison of fish assemblages as established by monoBRUV methodology.

Similarity Percentages

One-way SIMPER analysis revealed those species principally responsible for determining group similarities for Habitat. Group similarities are presented for the highest contributing species with a cut-off percentage of 25.0%. The Top 5 species per habitat are presented in Table 30.

Table 17. Highest assemblage similarities for each habitat and the relative contributions of the highest contributing species. ***L. mormyrus = Lithognathus mormyrus***

Species	**Mean Abundance**	**Mean Similarity**	**±StDev Similarity**	**Contribution %**	**Cumulative %**
		Seagrass - Average similarity: 86.76			
Diplodus annularis	3.40	5.55	2.88	6.39	6.39
Siganus luridus	2.28	3.59	3.45	4.14	10.53
Oblada melanura	2.33	3.55	3.00	4.09	14.62
Symphodus tinca	2.06	3.36	4.43	3.87	18.50
Diplodus sargus	2.00	3.21	4.17	3.70	22.20
		Rocky-Algal - Average similarity: 82.25			
Mugilidae sp.	2.75	4.61	1.54	5.60	5.60
Diplodus sargus	2.44	4.19	3.28	5.09	10.69
Oblada melanura	2.33	3.43	3.41	4.17	14.86
Sarpa salpa	2.23	3.39	2.00	4.12	18.98
Siganus luridus	2.02	3.20	3.51	3.90	22.88
		Sand - Average similarity: 89.11			
Mugilidae sp..	3.34	3.97	2.60	4.46	4.46
L. mormyrus	2.53	3.71	3.33	4.17	8.62
Diplodus sargus	2.07	3.64	3.43	4.09	12.71
Oblada melanura	2.45	2.61	3.96	4.05	16.75
Sarpa salpa	2.01	3.22	5.15	3.63	20.38

SIMPER revealed noticeable divisions in the relative contributions of seafood species between habitat types. This was most marked in Sand habitats, whose principal contributions were again made by the species of Grey mullet (Mugilidae sp) and the Sand steenbrass (*Lithognathus mormyrus*). Grey mullet were also principal contributors to Rocky-Algal habitats in contrast to Seagrass which were principally represented by the Annular seabream (*Diplodus annularis*).

6.5.3 Capture and Release Nets (CRN)

General description of species distribution patterns

Capture and Release Nets were deployed over three seasons; Winter, Spring and Autumn. A total of 369 individuals (from 37 species, 19 families) were caught by 810 individual CRN deployments (486 Fyke, 324 Minnow). *Posidonia oceanica* seagrass was targeted 363 times (Fyke 226, Minnow 137), Rocky-Algal habitat 147 times (Fyke 85, Minnow 62), and sand 300 times (Fyke 175, Minnow 125). The Damsel fish (*Chromis chromis*) was the most caught species by Fyke net n=27, followed by the Annular seabream (*Diplodus annumlaris*) n=21 and the Surmullet (*Mullus surmulletus*) / Painted Comber (*Serranus scriba*), both n=20. The Muglidae sp. n=86, were the most caught by the Minnow nets (a school of 82 of these individuals were caught on just one occasion). Aside from this result, the Annular seabream (*Diplodus annumlaris*) n=21 / Damsel fish (*Chromis chromis*) n=21, and the Mediterranean Rainbow wrasse (*Coris julis*) n=15, were the most caught species by Minnow net.

A comparable total number of species (total species richness) was recorded from Rocky-algal (15) and sand (13) habitats, in comparison with *Posidonia* seagrass meadows (27) (Table 31).

Table 18. Number of species recorded in each of the three habitats. Dashed lines link total species found in Rocky-Algal habit with Seagrass and Sand habitats. Solid lines link Seagrass and Sand habitats.

	Habitat		
Type of species	**Seagrass**	**Rocky-algal**	**Sand**
Unique species	9	1	6
Total species	27	15	13
Shared between two habitats	5	4	2
Shared among three habitats		4	
Total number of species		37	

5 of the 9 species unique to seagrass were Wrasse (Labridae), the other 4 were the three important fishery species; Saddled seabream (*Oblada melanura*), Brown meagre (*Sciaena umbra*) and Slipper lobster (*Scyllarides latus*), and a species of Goby (*Gobius cruentatus*). Table 32 shows mean size and life stages of fish caught by CRN methods.

Table 19. Mean Total Length (TL) and Length at Maturity (Lm) for species captured by Capture and Release Nets. Where FishBase (2016) Lm data is unavailable the rule of thumb of 1/3 Max Length has been used. No data is presented for *Octopus vulgaris*. Data for individual nets are available in Appendix D (Fyke) and Appendix E (Minnow). Species associated with the Small-Scale Capture Fishery are highlighted in grey.

Family	**Species Name**	**Fyke Net TL (Mean ± SD)**	**Minnow Net TL (Mean ± SD)**	**Length at Maturity (cm)**	**Life Stage (<Lm or >=Lm)**
Apogonidae	*Apogon imberbis*	8.5 (±0.8)	-	5.5	Adult
Bothidae	*Arnoglosus thori*	12.5 (±0.0)	-	12.0	Adult
	Bothus podas	8.5 (±2.8)	10.7 (±3.2)	14.1	Juvenile
Carangidae	*Trachinotus ovatus*	-	7.2 (±0.0)	23.3	Juvenile
Centracanthidae	*Spicara smaris*	11.5 (±0.0)	-	9.1	Adult
Congridae	*Conger conger*	47.5 (±11.9)	46.4 (±47.5)	66.7	Juvenile
	Gnapthophus mystax	50.5 (±0.0)	40.0 (±0.0)	35.0	Adult
Gobiidae	*Gobius bucchichi*	8.0 (±0.0)	11.2 (±0.0)	3.4	Adult
	Gobius cobitis	-	12.6 (±0.0)	9.0	Adult
	Gobius cruentatus	-	8.8 (±0.0)	6.0	Adult
Labridae	*Coris julis*	11.5 (±2.9)	10.7 (±1.8)	10.0	Adult
	Symphodus cinereus	7.9 (±0.8)	6.5 (±0.4)	4.0	Adult
	Symphodus doderleini	-	10.4 (±0.0)	5.4	Adult
	Symphodus ocellatus	10.5 (±3.7)	7.0 (±1.7)	4.0	Adult
	Symphodus roissali	10.1 (±0.0)	8.1 (±1.3)	5.6	Adult
	Symphodus rostratus	7.1 (±1.4)	-	4.3	Adult
	Symphodus tinca	12.1 (±1.6)	-	10.0	Adult
	Pteragogus pelycus	7.6 (±1.7)	6.1 (±0.0)	5.0	Adult
	Xyrichtys novacula	14.6 (±0.0)	-	12.6	Adult
Monocanthidae	*Stephanolepis diaspros*	8.2 (±0.0)	-	8.5	Juvenile
Muglidae	*Spp.*	-	9.0 (±2.2)	35.4	Juvenile
Mullidae	*Mullus surmulletus*	13.3 (±2.2)	-	16.1	Juvenile
Muraenidae	*Muraena helena*	65.0 (±0.0)	60.0 (±16.6)	75.5	Adult
Pomacentridae	*Chromis chromis*	9.7 (±1.1)	8.2 (±1.6)	6.3	Adult
Scianidae	*Sciaena umbra*	22.4 (±0.0)	-	25.0	Juvenile
Scorpaenidae	*Scorpaena notata*	10.4 (±0.0)	9.3 (±0.4)	8.0	Adult
	Scorpaena porcus	14.2 (±3.1)	10.4 (3.6)	14.4	Juvenile
Serranidae	*Serranus cabrilla*	10.1 (±1.5)	11.1 (±0.4)	17.5	Juvenile

	Serranus hepatus	11.0 (±0.0)	-	7.8	Adult
	Serranus scriba	13.6 (±2.4)	11.7 (±3.3)	17.3	Juvenile
Sparidae	*Boops boops*	16.7 (±1.6)	9.9 (±0.0)	13.0	Adult
	Diplodus annularis	9.2 (±3.0)	9.5 (±2.4)	11.2	Juvenile
	Sparus aurata	-	27.1 (±0.0)	20.0	Juvenile
	Oblada melanura	5.2 (±0.2)	-	20.0	Juvenile
Synodontidae	*Synodontidae*	19.1 (±3.3)	-	13.3	Adult
Sepiidae	*Sepia officinalis*	15.5 (±6.8)	13.0 (±0.0)	10.0	Adult
Scyllaridae	*Scyllarides latus*	3.5 (±0.0)	-	8.5	Juvenile

Mean overall capture per deployment was highest in *Posidonia oceanica* seagrass (Fyke 0.57 ±3.47; Minnow 0.47 ±2.03), second in rocky-algal habitat (Fyke 0.24 ±0.77; Minnow 0.35 ±1.29) and lowest on un-vegetated sandy bottoms (Fyke (0.19 ±0.13; Minnow 0.14 ±0.57) (Figure 115). Therefore, for overall species assemblages, average seagrass showed for Fyke nets ≈2.79 times and rocky algal ≈1.26 times the abundance densities of un-vegetated sandy bottom habitats. For minnow nets, on average, seagrass showed ≈3.36 times and rocky algal ≈2.50 times the abundance densities of un-vegetated sandy bottom habitats.

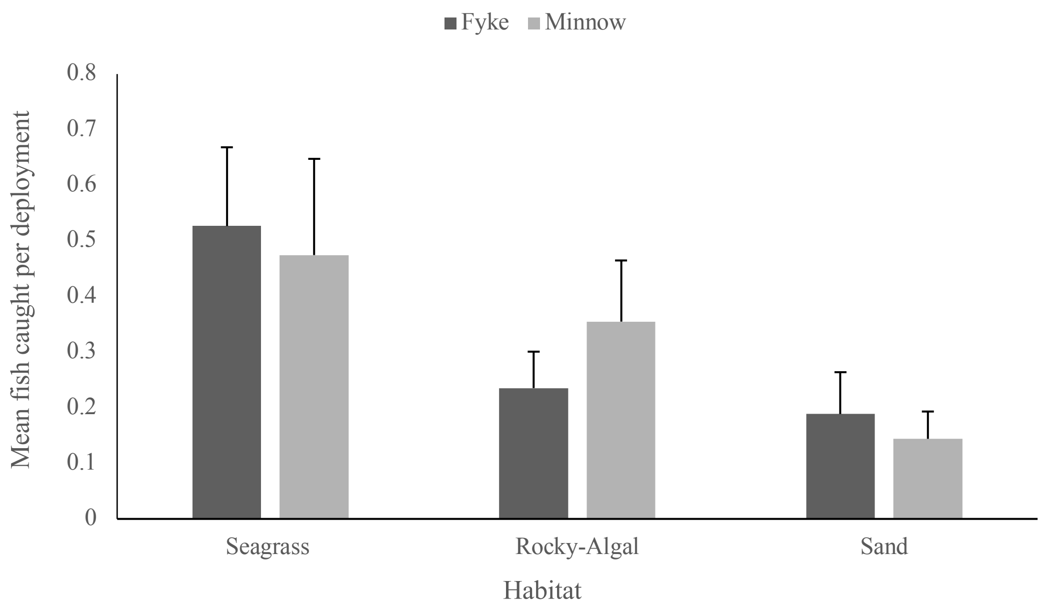


Figure 91. Mean fish caught per deployment, by habitat, for Capture and Release Nets (Fyke and Minnow).

When non-SCCF species were removed, and these figures were calculated only for SSCF species, mean capture per deployment was highest in seagrass (Fyke 0.33 ±6.13; Minnow 0.47 ±4.33), second in rocky-algal habitat (Fyke 0.14 ±4.69; Minnow 0.34 ±3.1) and lowest on sandy bottoms (Fyke (0.13 ±4.61; Minnow 0.13 ±1.26). For Fyke nets seagrass showed ≈2.54 times and rocky algal ≈1.08 times the abundance densities of un-vegetated sandy bottom habitats. For minnow nets, on average, seagrass showed ≈3.68 times and rocky algal ≈2.64 times the abundance densities of un-vegetated sandy bottom habitats. 78 individuals of the 174 SSCF species caught by CRN were juveniles.

Seasonally, the fewest fish were caught in Winter (Fyke; n=43 Minnow; n=21) followed by Spring (Fyke; n=68, Minnow; n= 24) and finally and then the most were caught in Autumn (Fyke; n=71, Minnow; n=142). These results support the UVC data in highlighting the importance of the Autumn season for small juvenile fish species that peaked in abundance during the summer months (see UVC size data above). Fifteen of the species caught were identified as of importance to the small-scale capture fishery, and of these, ten species had a mean total length was below the length of maturity making them juveniles of the species (Table 33) highlighting the importance of the shallow coastal waters as a valuable nursery habitat. Fyke and Minnow nets have slightly different selectivity and so their data are presented separately below; Fyke (Figure 116, Table 33) Minnow (Figure 117, Table 34).

Of the important fishery species caught by the CRN methods; the Pompano (*Trachinotus ovatus*), the Conger eel (*Conger conger),* Surmullet (*Mullus surmulletus*), Brown meagre (*Sciana umbra*), Black scorpionfish *(Scorpanea porcus*), Comber *(Serranus cabrilla*), Painted Comber *(Serranus scriba*), Saddled seabream *(Oblada melanura*) and Slipper lobster (*Scyllarides latus*) are i) of value to the SSCF (see Chapter 7), and ii) caught as 'juveniles' (below Lm). The Saddled seabream (*Oblada melanura*), Brown meagre (*Sciaena umbra*) and Slipper lobster (*Scyllarides latus*) were unique to seagrass meadows in the shallow coastal zone, whilst the remaining five species were captured in either seagrass and rocky-algal habitat types; Painted comber (*Serranus scriba*), Comber (*Serranus cabrilla*), rocky-algal and sandy bottoms; Conger eel (*Conger conger*), or across all three habitats;

Black Scorpionfish (*Scorpanea porcus*) and Surmullet (*Mullus surmulletus*). The Pompano (*Trachinotus ovatus*) is a pelagic species and therefore does not associate with any particular habitat type.

Those species of value to the small-scale fishery that were caught in the shallow coastal zone as adults (above Lm) include the Peacock wrasse *(Symphodus tinca*), the Mediterranean moray (*Muraena helena*), the seabreams Bogue (*Boops boops*), Picareal (Spicara smaris), and Gilthead seabrema (*Sparus aurata*) and the Common cuttlefish (*Sepia officinalis*). The Bogue (*Boops boops)* and Picarel (*Spicara smaris*) are common gregarious planktivourous species with patchy distributions (Guidetti, 2000). However, the capture of adults of high trophic level species of Gilthead seabream (*Sparus aurata*) and Mediterranean moray (*Muraena helena*) are likely attributable to foraging behaviours of these carnivorous species. In contrast, the presence of adult common cuttlefish (*Sepia officinalis*) is likely because they lay eggs in coastal seagrass meadows (Gibson, 2001; Pers. Obs.).

Figure 116 shows the relative rations (Juvenile vs Adult) for individuals of species caught by the Fyke nets during the survey. Table 33 shows mean size of all individuals caught by Fyke net for each species and the length of maturity (Lm) for each species.

Figure 117 shows the relative rations (Juvenile vs Adult) for individuals of species caught by the Minnow nets during the survey. Table 34 shows mean size of all individuals caught by Minnow net for each species and the length of maturity (Lm) for each species.

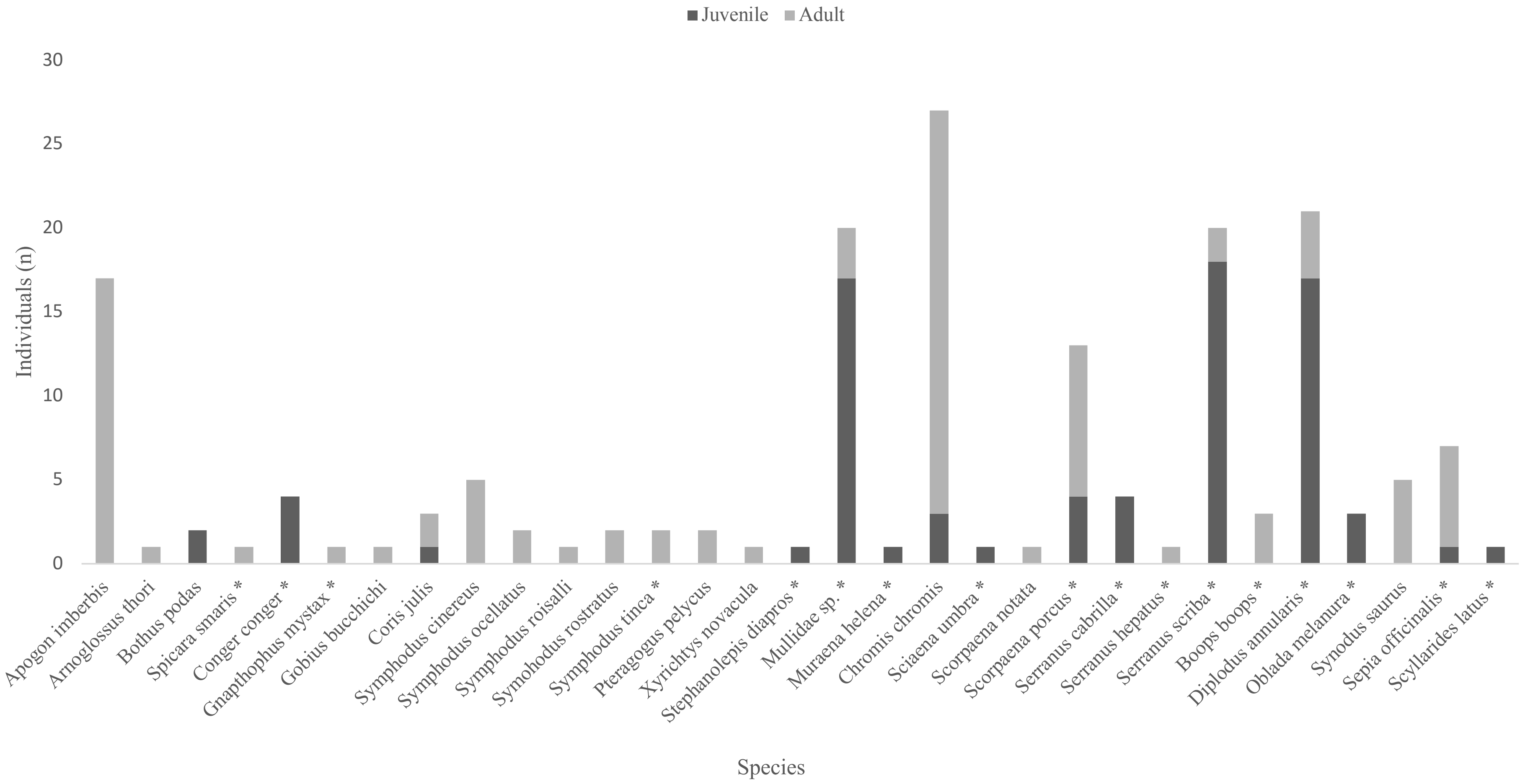


Figure 92. The relative ratio of individuals caught which were either i) Juvenile (caught below species Lm) or ii) Adult (caught above species Lm) for Fyke nets. * denotes focal species of importance to the small-scale capture fishery.

Table 20. Fyke Net mean fish size vs length at maturity (Lm). Where Lm data is unavailable the 'rule of thumb' of 1/3 Max Length has been used. Lm data from Tsikliras and Stergiou (2013) and FishBase (2016). Grey denotes focal species of importance to the small-scale capture fishery

Family	Species Name	Common Name	Size (Mean ± SD)	Length at Maturity (cm)	Max Length (cm)	Juvenile or Adult?
Apogonidae	Apogon imberbis	Cardinal fish	8.5 (±0.8)	5.5	15.0	Adult
Bothidae	*Arnoglosus thori*	Thor's Scaldfish	12.5 (±0.0)	12.0	18.0	Adult
	Bothus podas	Wide-eyed flounder	8.5 (±2.8)	14.1	45.0	Juvenile
Centracanthidae	*Spicara smaris*	Picarel	11.5 (±0.0)	9.1	20.0	Adult
Congridae	*Conger conger*	Conger eel	47.5 (±11.9)	75.0	200.0	Juvenile
	Gnathophis mystax	Thinlip conger	50.5 (±0.0)	20.0	60.0	Adult
Gobiidae	*Gobius bucchichi*	Bucchichi's goby	8.0 (±0.0)	3.3	10.0	Adult
Labridae	*Coris julis*	Mediterranean Rainbow wrasse	11.5 (±2.9)	10.0	30.0	Adult
	Symphodus cinereus	Grey wrasse	7.9 (±0.8)	4.0	12.0	Adult
	Symphodus ocellatus	Ocellated wrasse	10.5 (±3.7)	4.0	12.0	Adult
	Symphodus roissali	Five spotted wrasse	10.1 (±0.0)	5.7	17.0	Adult
	Symphodus rostratus	Pointed snout wrasse	7.1 (±1.4)	4.3	13.0	Adult
	Symphodus tinca	Peacock wrasse	12.1 (±1.6)	10.0	44.0	Adult
	Pteragogus pelycus	Sideburn wrasse	7.6 (±1.7)	5.0	15.0	Adult
	Xyrichtys novacula	Cleaver wrasse	14.6 (±0.0)	12.0	38.0	Adult
Monacanthidae	*Stephanolepis diapros*	Reticulated leatherjacket	7.1 (±0.0)	8.3	25.0	Juvenile
Mullidae	*Mullus surmulletus*	Red mullet	13.3 (±2.2)	16.1	40.0	Juvenile
Muraenidae	*Muraena helena*	Mediterranean moray	65.0 (±0.0)	75.5	150.0	Adult
Pomacentridae	*Chromis chromis*	Damsel fish	9.7 (±1.1)	8.3	25.0	Adult
Scianidae	*Sciaena umbra*	Brown meagre	22.4 (±0.0)	25.0	70.0	Juvenile
Scorpaenidae	*Scorpaena notata*	Small red scorpionfish	10.4 (±0.0)	8.0	24.0	Adult

	Scorpaena porcus	Black scorpionfish	14.2 (±3.1)	14.4	37.0	Juvenile
Serranidae	*Serranus cabrilla*	Comber	10.1 (±1.5)	17.5	40.0	Juvenile
	Serranus hepatus	Brown comber	11.0 (±0.0)	7.8	25.0	Adult
	Serranus scriba	Painted comber	13.6 (±2.4)	17.3	36.0	Juvenile
Sparidae	*Boops boops*	Bogue	16.7 (±1.6)	13.0	36.0	Adult
	Diplodus annularis	Annular seabream	9.2 (±3.0)	11.2	24.0	Juvenile
	Oblada melanura	Saddled seabream	5.2 (±0.2)	16.4	34.0	Juvenile
Synodontidae	*Synodontidae*	Synodus saurus	19.1 (±3.3)	13.3	40.0	Adult
Sepiidae	*Sepia officinalis*	European Cuttlefish	15.5 (±6.8)	10.0	30.0	Adult
Scyllaridae	*Scyllarides latus*	Slipper Lobster	3.5 (±0.0)	-	-	Juvenile

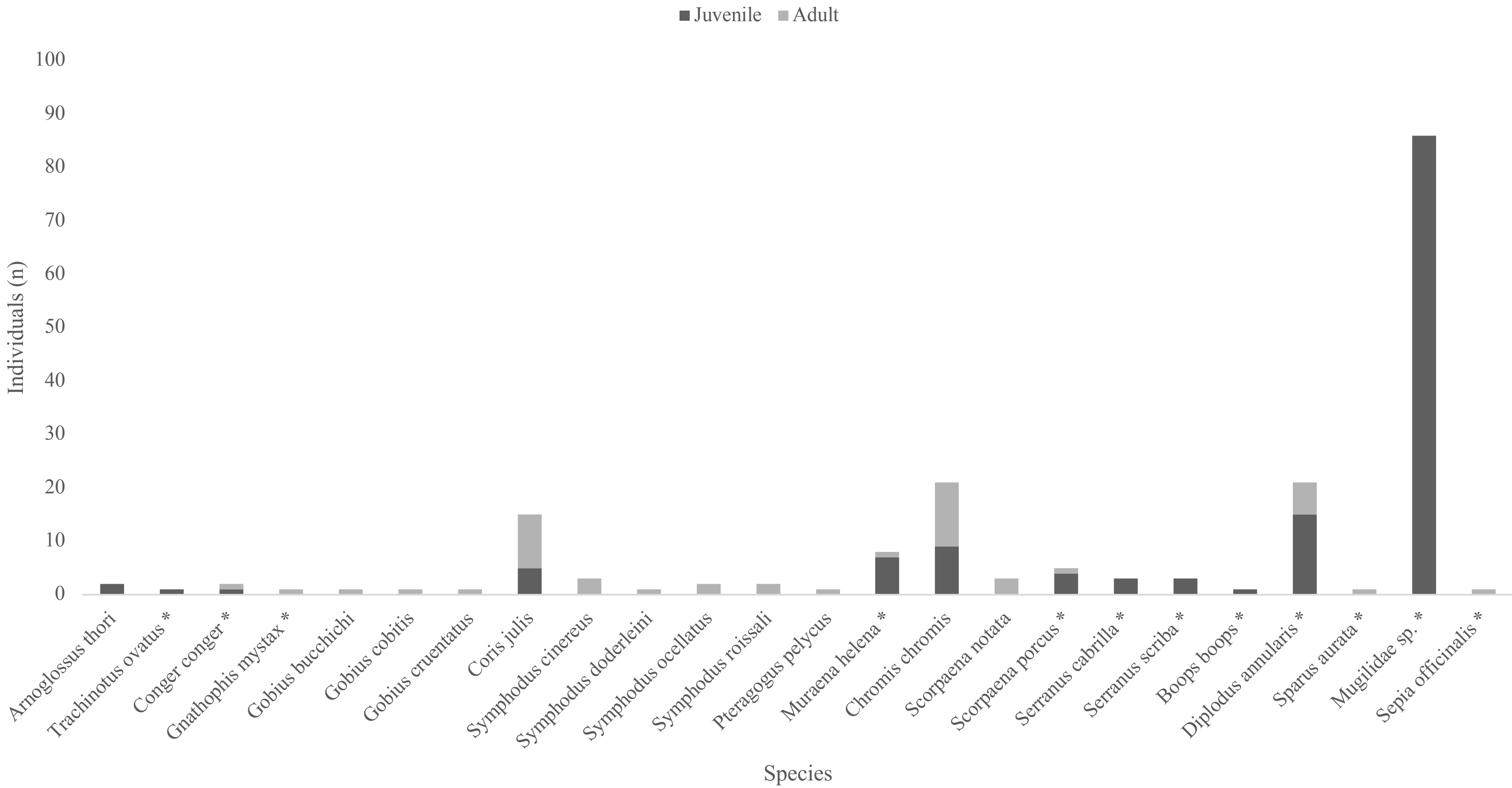


Figure 93. The relative ratio of individuals caught which were either i) Juvenile (caught below species Lm) or ii) Adult (caught above species Lm) for Minnow nets. * denotes focal species of importance to the small-scale capture fishery.

Table 21. Minnow Net Mean Fish Size vs Length at Maturity. Where Lm data is unavailable the rule of thumb of 1/3 Max Length has been used. *Mugil cephalus* data has been used as a proxy for *Muglidae sp.* * denotes focal species of importance to the small-scale capture fishery

Family	Species Name	Common Name	Size (Mean ± SD)	Length at Maturity (cm)	Max Length (cm)	Juvenile of Adult?
Bothidae	*Bothus podas*	Wide-eyed flounder	10.7 (±3.2)	14.1	45.0	Juvenile
Carangidae	*Trachinotus ovatus*	Pompano	7.2 (±0.0)	25.6	70.0	Juvenile
Congridae	*Conger conger*	Conger eel	46.4 (±47.5)	75.0	200.0	Juvenile
	Gnathophis mystax	Thinlip conger	50.5 (±0.0)	20.0	60.0	Adult
Gobiidae	*Gobius bucchichi*	Bucchichi's goby	11.2 (±0.0)	3.3	10.0	Adult
	Gobius cobitis	Giant goby	12.6 (±0.0)	9.0	27.0	Adult
	Gobius cruentatus	Red mouthed goby	8.8 (±0.0)	6.0	18.0	Adult
Labridae	*Coris julis*	Mediterranean Rainbow wrasse	10.7 (±1.8)	10.0	30.0	Adult
	Symphodus cinereus	Grey wrasse	6.5 (±0.4)	4.0	12.0	Adult
	Symphodus doderleini	Doderleins wrasse	10.4 (±0.0)	5.3	16.0	Adult
	Symphodus ocellatus	Ocellated wrasse	7.0 (±1.7)	4.0	12.0	Adult
	Symphodus roissali	Five spotted wrasse	8.1 (±1.3)	5.7	17.0	Adult
	Pteragogus pelycus	Sideburn wrasse	6.1 (±0.0)	5.0	15.0	Adult
Muraenidae	*Muraena helena*	Mediterranean moray	60.0 (±16.6)	75.5	150.0	Juvenile
Pomacentridae	*Chromis chromis*	Damsel fish	8.2 (±1.6)	8.3	25.0	Juvenile
Scorpaenidae	*Scorpaena notata*	Small red scorpionfish	9.3 (±0.4)	8.0	24.0	Adult
	Scorpaena porcus	Black scorpionfish	10.4 (3.6)	> 14.4	37.0	Juvenile
Serranidae	*Serranus cabrilla*	Comber	11.1 (±0.4)	> 17.5	40.0	Juvenile
	Serranus scriba	Painted comber	11.7 (±3.3)	> 17.3	36.0	Juvenile
Sparidae	*Boops boops*	Bogue	9.9 (±0.0)	> 13.0	36.0	Juvenile
	Diplodus annularis	Annular seabream	9.5 (±2.4)	> 11.2	24.0	Juvenile
	Sparus aurata	Guilthead seabream	27.1 (±0.0)	> 20.0	70.0	Adult
Mugilidae*	Mugilidae sp.	Mullet species.	9.0 (±2.2)	> 35.4	100.0	Juvenile
Sepiidae	*Sepia officinalis*	European Cuttlefish	13.0 (±0.0)	10.0	30.0	Adult

6.5.4 Synergies and Triangulation

Species Size

Underwater Visual Census revealed that for each of the 20 most common habitat-associated SSCF species, the clear majority (98.9%) of individuals recorded were juveniles or intermediates of the species. However, by comparison, Capture and Release nets revealed just 45% of species captured Fyke nets to be juveniles; 74.2% of these captures occurred during the night with 25.8% occurring during the day), From Minnow nets, 74.0% of species captured were juveniles; 74.8% of the captures occurring at night with 25.1% of captures occurring during the day. These results suggest that whilst the shallow coastal zone is principally being used as a nursery habitat, the presence of larger individuals, caught primarily in seagrass meadows, and during the night, might indicate the use of this habitat as a foraging ground for adults. Individuals from seven principal fishery species (*Symphodus tinca, Mullus surmulletus, Serranus cabrilla, Serranus scriba, Diplodus annularis, Sparus aurata, Oblada melanura*) were also caught by the Capture and Release Nets, and except for the Peacock Wrasse (*Symphodus tinca)*, the mean size of these individuals caught made them juveniles of the species.

Species Presence

The CRNs also elicited the presence of other important fisheries species that were not recorded by either the UVC or monoBRUV methods (that rely on line of sight) and which tend to live 'within' the seagrass canopy or crevices in rocks. These included species of Congridae (*Conger conger, Gnathophis mystax*) Scorpaenidae (*Scorpaena porcus*), Scianade (*Sciana umbra*) and Scyllaridae (*Scyllarides latus*).

The repeat occurrence of juvenile scorpionfish (Scorpaenidae) in *Posidonia oceanica* seagrass meadows (Figure 118) is an important finding considering their importance to the SSCF (see Chapter 7), as is the presence in seagrass of juvenile Mediterranean slipper lobster (*Scyllarides latus*) which are highly esteemed and command a strong economic value (≈€35/kg) locally.

Figure 94. Scorpionfish (Scorpaenidae) are often under-represented by Underwater Visual Census because they live within the seagrass canopy.

Species richness

Table 35 shows the species richness rankings for each habitat across seasons. Habitats are ranked (3) for when the species richness was highest in that habitat, (2) for second richest habitat and (1) for least rich, for each method in each season. If a habitat scores 9, then there is universal agreement between methods over species richness rankings. Figures lower than 9 are the result of conflicting results from the different methods used in this study.

Table 22. Species richness rankings for each habitat type. 3 denotes the richest habitat, 2 the middle, 1 the least diverse.

Method	Rank	*Winter*	*Spring*	*Summer*	*Autumn*
	3	**Seagrass**	**Rocky-Algal**	**Seagrass**	**Seagrass**
APC	**2**	**Rocky-Algal**	**Seagrass**	**Rocky-Algal**	**Rocky-Algal**
	1	**Sand**	**Sand**	**Sand**	**Sand**
	3	**Seagrass**	**Seagrass**	**Rocky-Algal**	**Rocky-Algal**
ABT	**2**	**Rocky-Algal**	**Rocky-Algal**	**Seagrass**	**Seagrass**
	1	**Sand**	**Sand**	**Sand**	**Sand**
	3	**Rocky-Algal**	**Rocky-Algal**	**Seagrass**	**Seagrass**
BRUV	**2**	**Seagrass**	**Seagrass**	**Rocky-Algal**	**Rocky-Algal**
	1	**Sand**	**Sand**	**Sand**	**Sand**
Combined Richness Rank		**Seagrass (8)** **Rocky Algal (7)** **Sand (3)**	**Rocky-Algal (8)** **Seagrass (7)** **Sand (3)**	**Seagrass (8)** **Rocky Algal (7)** **Sand (3)**	**Rocky-Algal (8)** **Seagrass (7)** **Sand (3)**

Triangulation reveals that there was no universal agreement between methods as to whether seagrass meadows or rocky-algal habitats displayed the greatest species richness in any given season. However, there was universal agreement that both seagrass and rocky-algal habitats are more speciose than un-vegetated bare sand habitats.

Species abundances

Table 36 shows the relative species abundance figures for each habitat across seasons in comparison to the least productive un-vegetated sandy bottom habitat.

Table 23. Relative overall ratios of species abundance from each of the three methods (Underwater Visual Census, Baited Remote Underwater Video and Capture and Release Nets) deployed in this study in comparison to bare sand. Underwater Visual Census and Capture and Release Net methods presented both in isolation and together.

Habitat	Relative Species Abundance (times higher than sand)						
	UVC	APC	ABT	**BRUV**	**CRN**	**Fyke**	**Minnow**
Seagrass	**5.4**	6.5	4.2	**1.7**	**3.1**	**2.5**	**3.7**
Rocky-Algal	**4.4**	5.0	3.7	**2.8**	**1.9**	**1.1**	**2.6**
Sand	**1.0**	1.0	1.0	**1.0**	**1.0**	**1.0**	**1.0**

All methods used in this study revealed that both *Posidionia oceanica* seagrass meadows and rocky-algal habitats had higher SSCF associated species assemblage abundances than un-vegetated bare sand habitats.

Species-habitat associations

SIMPER and nMDS data reveal that whilst some species such as Saddled seabream (*Oblada melanura)* or the Annular seabream (*Diplodus annularis*) provision the seafood supply chain from production in multiple habitats (i.e. rocky-algal habitat and seagrass meadows), others are exclusive to individual habitat types, for example the Dusky spinefoot (*Siganus luridus*) for seagrass on the Sand steenbrass (*Lithognathus mormyrus*) for un-vegetated sandy bottoms.

Species trophic levels

Mean Trophic Levels for recorded fish assemblages were calculated for both Underwater Visual Census methods and for the Baited Remote Underwater Video data. Trophic level estimates for fish, based on their diet composition, may be found in FishBase (a global online database on fish). FishBase data was then combined with the abundance data generated from this study to calculate the Mean Trophic Level for the assemblages of the coastal zone from each method:

3.28 = for Apnea Point Count

3.32 = for Apnea Belt Transect

3.12 = for Baited Remote Underwater Video

Next, species were aggregated into four trophic level classes: A = 2.00-3.00, B =3.01-3.50, C = 3.51-4.00 and D = 4.01-4.50 (as per classes provided by Stergiou 2005 for Hellenic fisheries). The relative ratios of lower to higher trophic level species are presented for each method in Table 37.

Table 24. Underwater Visual Census and Baited Remote Underwater Video data showing the mean trophic levels of species assemblages observed in the coastal zone.

Trophic Class (A, B, C or D)	Fish abundance (n)	Percentage of total assemblage (%)
APC data:		
A	1939	25
B	3331	44
C	2210	29
D	167	2
ABT data:		
A	1826	22
B	5045	51
C	1165	24
D	288	3
BRUV data:		
A	5004	37
B	5525	41
C	2538	19
D	533	4

Tsikliras et al. (2007), found that fish with trophic levels ranging between 3 and 3.5 dominated the fisheries catch in Greek waters from 1950-2001 (62% of species landed), this is supported by this observed assemblage data, where recorded individuals contributed between 41%-51% of the Class B individuals recorded in species assemblages across methods (Table 37)

In contrast to Tsikliras et al. (2005) catch data however, the individuals contributing to assemblage trophic level in this study were mainly represented by the wrasse *Coris julis* and the seabreams *Oblada melanura* and *Diplodus sargus*, and the goatfish *Mullus surmulletus*.

Fish species with trophic levels from 3.5 to 4.0 contributed between 19-29% to the mean total and were mainly composed of contributions from the seabreams *Diplodus annularis* and *Sparus aurata*, and the Damselfish *Chromis chromis*. Finally, the species groups with the lowest and highest trophic levels (i.e., 2.0-3.0 and 4.0-4.5, respectively) contributed between 22-37% and 2-4% to the mean total respectively. The lowest trophic level class was mainly characterised by the abundance of the invasive Rabbitfish *Siganus luridus* and the grey mullets (Muglidae), but also due to the abundance of the seabreams *Boops boops* and *Sarpa salpa*. In contrast, the few species recorded from the highest trophic levels were dominated by Barracuda, Jacks and Pompano species (Sphyraenidae and Carangidae) whose juveniles appear to utilise the coastal zone as a nursery habitat.

6.6 Discussion

In this chapter, interrogation of the distribution and characteristics of species assemblages adopted a triangulated approach, with species distribution interrogated utilising three complimentary techniques: Underwater Visual Census (UVC), Baited Remote Underwater Video (BRUV) and Catch and Release Nets (CRN). Through this approach species-habitat associations and species characteristic data relevant to effective Small Scale Capture Fishery (SSCF) Sustainable Supply Chain

Management (SSCM) was documented using each method and the synergies between them articulated.

Through adopting this multi-method approach a more complete picture of the seafood species (products) present in coastal habitats (suppliers) has been established. It has been possible to identify both the abundance and variety of locally available species and to identify which species associate with which habitat types. The data indicates that these coastal fish assemblages are in a dynamic state, and that for SSCM, close consideration needs to be paid to the heterogeneous distribution of these habitat-associated marine species.

Understanding the connections between habitat and species assemblages is essential to the proposed Small-Scale Capture Fishery conceptual framework since it moves us beyond a 'catch to market' approach and the conceptualisation of the seas and oceans like a homogenous seafood supplier (i.e. it is evidenced that specific suppliers provide specific seafood products that are rooted in place).

From a Sustainable Supply Chain Management (SSCM) perspective, it has been possible to quantitatively establish which habitats support the greater abundance, and the greater richness of species (i.e. variety and volume of product supply). Such knowledge can inform effective Ecologically Dominant Supply Chain Management (ED-SCM) where management decisions regarding the type of extractive fishing gears and the level of fishing effort can be made appropriate to the supplier in question.

Finally, this approach enabled the quantification of adult to juvenile ratios within the coastal zone and through consultation with FishBase (2016) trophic level data to determine the mean trophic levels of the species in the assemblages recorded. The abundance of juveniles in the shallow habitats of the coastal zone supports the assertion that these areas are important nursery habitat. In addition, the observation of very few Class D (Predatory) species supports this argument, but could also be an indication of the fishing down of marine food webs in Greek seas.

6.6.1 Relevance to Small-Scale Capture Fisheries Sustainable Supply Chain Management

The principal SSCM challenge relating to the SSCF that has been identified within this chapter is the capacity for managers to enable the right 'choice' of product to be extracted by the industry to meet the end-consumers demand. The methods involved in this extraction is often a trade-off linked to the capacity to extract from a habitat based on its a) product richness, b) product abundance and (c) product maturity and trophic level.

Habitat differences in species richness

There were statistically significant differences in species richness between seasons, yet there was no universal agreement between the methods employed (APC, AST and monoBRUV) as to whether *Posidonia oceanica* seagrass meadow or rocky-algal habitat showed the highest mean species richness in any given season.

However, what is clear, is that both habitats show much greater mean species richness than un-vegetated sandy bottoms over all four seasons, and that the general trend for species richness across seasons is for lower richness values in winter, a slight growth in spring, a peak in summer and a marginal drop off in autumn heading into the following winter. This is in line with what would be expected with typical latitude related seasonal changes and changes in habitat structure (i.e. growth of seagrass canopy and epiphytic algal structures offering a more complex suite of micro-habitats for novel species) and habitat function (i.e. increased primary productivity providing energy to the base of the marine food web)

This knowledge is important to effective SSCF SSCM since it is the protection of both habitat complexity, and habitat primary productivity that is required to ensure continuity of supply and in currently under threat from inappropriate fishing techniques that damage habitat.

Habitat differences in species abundances

There were statistically significant differences in species abundances between habitats, yet there was no universal agreement between the methods employed (APC, ABT and monoBRUV) as to whether *Posidonia oceanica* seagrass meadow or rocky-algal habitat showed the highest mean species abundance. However, what is clear, is that both seagrass and rocky-algal habitats show much greater mean species abundance than un-vegetated sandy bottoms over all four seasons, and that the general trend for species abundances across seasons is for lower abundance values in winter, a slight growth in spring, a peak in summer and a drop off in numbers through autumn heading into the following winter.

This knowledge is important because it directly indicates the value of rocky-algal reef and *Posidonia oceanica* seagrass meadows to fisheries provision. This chapter has been able to link valuable fishery species, in particular the commercially important seabreams to these complex habitats and support the assertion that these shallow coastal habitats act as nursery grounds in the summer months.

Stock maturity and trophic level

Over 4 in every 5 species (82.9% of all individuals were juveniles, or 83.4% of fishery species) observed in the shallow coastal zone were juveniles of the species. Additionally, between 22-37% were Class A (low trophic level fish) with only 2-4% of individuals Class D (high trophic level fish). This data points to the shallow coastal zone (<10m) as nursery habitat that is unsuitable for targeted extraction (young fish) but also to the paucity of high-trophic level species in the coastal waters.

6.6.2 Management Recommendations

The application of this triangulated approach to investigating habitat-associated species assemblages represents one of the most extensive coastal assemblage surveys undertaken in the Aegean Sea. On this basis, weight can be given to the identified species-habitat associations revealed in the data.

Using the ecologically dominant research logic, the SSCM decisions that ensure the protection of those habitats that supply the greatest diversity and abundance of seafood products, namely the *Posidonia oceanica* seagrass meadows and the Rocky-algal formations must be the initiatives that are championed. This must be done so based on the need to protect essential marine biodiversity and valuable nursery habitat (Giakoumi et al., 2011).

From a consumer perspective (see Chapter 9), the protection of this priority habitats is also a desirable SSCM initiative, since it is this seagrass habitat that provisions the consumer with greatest abundance and diversity of commercially desirable species i.e. Saddled seabream (*Oblada melanura*), Gilthead seabream (*Sparus aurata*), Black seabream (*Spondyliosoma cantharus*), Cuttlefish (*Sepia officinalis*) and Barracuda (Sphyraenidae), as well as a number of species that contribute to island household food security i.e. Dusky spinefoot (*Siganus luridus*), and a variety of Scorpionfish (Scorpaenidae).

However, failing to protect Rocky-Algal habitat would limit the provision of species such as the Mediterranean Parrotfish (*Sparisoma cretense*), the Two-banded seabream (*Diplodus vulgaris*) and a number of high-value / low abundance species such as the Golden grouper (*Epinephelus costae*) and Dusky grouper (*Epinephelus marginatus*) were only recorded in rocky-algal habitat.

What this chapter has also demonstrated is that the least productive ‘sand’ habitat contributes the least to the SSCF seafood supply chain. The sand-associated Sand steenbrass (*Lithognathus mormyrus*) and Grey Mullet (Muglidae) do not feature prominently in the SSCF (Chapter 7) and therefore protection of this habitat will do little to ensure the sustainability of seafood supply.

In this chapter, the management objective aligns to the protection of complex 3D habitat as the primary supplier of habitat-associated species that provision the SSCF supply chain (and therefore the SSCM of supply side seafood security). This finds itself in line with the trends documented by other authors, both in the Mediterranean (Guidetti, 2000); and elsewhere; USA (Sogard and Able, 1991), Australia (Jenkins & Wheatley, 1998); which shows that the mean species richness and mean species abundance follows the hierarchy of being higher over submerged aquatic vegetation (in this case *Posidonia oceanica* seagrass) and complex rocky and algal structures, in comparision to by the species richness and species abundances found over bare sand. The cluster analyses performed on the data presented here shows that fish assemblages from *Posidonia* seagrass and rocky–algal reef habitats were more similar to each other, and well separated from that recorded over bare sand habitats, regardless of the sampling site and season.

These patterns lead to the conclusion that physical structure is one of the central (but not exclusive) factors that affect the general characteristics (richness, density) of habitat associated species assemblages and that although the differences between seagrass meadows and rocky-algal habitats are less marked, the key concern to sustainability of seafood supply is therefore the association of valuable seafood species to seagrass meadows that are being lost (see Chapter 5) from the local environment.

The data collected within this 'Assemblage' chapter also highlights some of the contrasts between SSCF SSCM and conventional SCM. For example: in a conventional supply chain, it is likely that a specific product would be explicitly linked to one supplier, rather than needing to understand the *'association and connectivity'* of multiple products to and between multiple suppliers. In addition, in a conventional supply chain, understanding inter-product interactions in the supply chain is not regularly an issue (i.e. product A could eat product B whilst with the supplier!).

6.6.3 Limitations and Future Research

As with any approach, the selection of survey techniques and detail represents a compromise. BRUV is the only method that reported higher abundance figures for rocky-algal habitat than seagrass. It also is the method that presented the lowest relevant abundances (e.g. just 1.7 times for seagrass and 2.8 times for rocky-algal habitats). Despite every effort to try to ensure that maximum visibility was achieved for the BRUV cameras (e.g. visible horizon, camera deployment parallel to the substrate) there is an inherent bias with sampling methods that rely solely on uni-directional line of sight, since the camera cannot move around in a three-dimensional habitat structure to count a species, which is something that is achievable by UVC. As such it can be argued that BRUVS would be likely to over-represent species abundance and diversity over homogenous flat substrates (e.g. bare sand), but then likely under-represent species in more complex three dimensional habitats (e.g. seagrass meadows). This may explain the values reported by the BRUV systems.

Excluding the BRUV data (on the above basis), then across seasons and sites, fish densities were higher in *Posidonia oceanica* seagrass meadows and rocky-algal habitat formations which were in turn higher than over bare sand. This finding supports the hypothesis that the provision of complex, three-dimensional physical structure is one of the main factors affecting coastal fish assemblages rather than finer habitat characteristics (Bell et al., 1987; Guidetti 2000).

It is worth nothing that the data analysis in this chapter generally pertains to the faunal assemblages recorded by daytime censuses. It is only the capture and release nets that produced any dial data that could provide insight into habitat association over a daily cycle. Other authors have observed variation in both assemblage composition and trophic structure during the day-night cycle, both in the Mediterranean (e.g. Harmelin-Vivien, 1982; Bell and Harmelin-Vivien, 1982) and elsewhere; Indonesia, (Unsworth et al., 2008) and the Caribbean (Baker et al., 2015). In most cases the authors have attributed an increased abundance and diversity of fish fauna at night to either nocturnal immigration of foraging carnivores, but also to diurnal movements of planktivore's in the water column.

CHAPTER 7 - Supply Chain Stage 3 - Fishery

7.1 Introduction

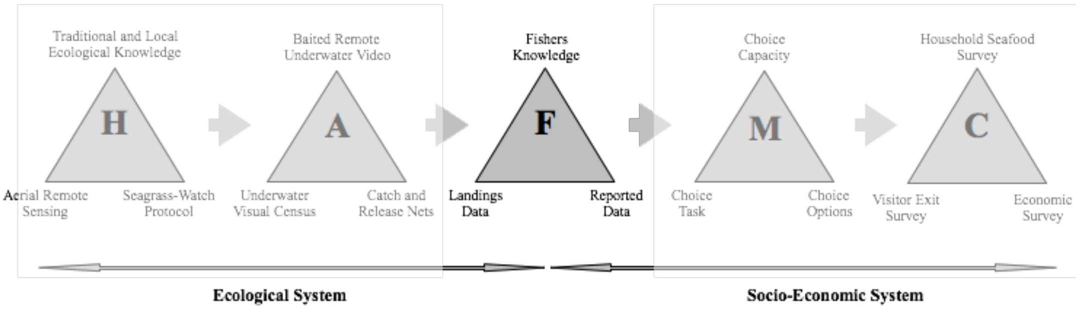


Figure 95. This chapter focuses on the Fishery (F) as the extractive industry, and the third stage of the Small-Scale Capture Fishery supply chain. This supply chain stage is located within what would be conventionally conceptualised as the meeting point of both the ecological and socio-economic systems.

The third stage in the Small-Scale Capture Fishery (SSCF) supply chain framework represents the 'extractive' stage of the industry, and it sits at the boundary of the ecological (habitat & assemblage) and socio-economic (market & consumer) systems (Tzanatos et al., 2006a; Peterson and Fronc, 2007; Kittinger et al., 2013; Béné et al., 2016). In this study, the social and economic context of Lipsi Island (the place in which the SSCF is located) will directly inform the demand for specific seafood products in the supply chain. The ecological context (place) in which the SSCF is located will directly affect the seafood supply, and therefore the supply chains capacity to meet that seafood demand.

The concept of social-ecological systems (SES) framework has been championed (e.g. Ostrom, 2009) to stress the coupled nature of humans and the environment (Or the concept that culture and nature is inherently intertwined). To date the social-ecological systems framework has been used to explore the perceived resilience of extractive industries such as fisheries (e.g. McClanahan et al, 2009). Such a framework helps to capture the complexity of the systems and the linkages that occur through feedback mechanisms (Folke et al., 2003; Kittinger et al., 2013).

In the proposed SSCF SSCM framework presented in this study, such feedbacks can be expressed as changes in demand or supply of seafood products. For example, the demand created for a specific seafood species by the 'Consumer' in the 'Market' place will feedback to the 'Fishery' generating pressure to extract that species from the species 'Assemblage' associated to a specific 'Habitat'. Or, in contrast, a change in the natural environment (e.g. the growth of an invasive species OR increasing surface sea temperature related to climate change) could decrease the size and extent of a given 'Habitat', leading to decreased supply of desirable species' from the associated 'Assemblage'.

Critically, the proposed Small-Scale Capture Fishery Supply Chain framework is about simplifying a complex system, and enabling SSCF managers to articulate seafood SSCM initiatives using a common and accessible framework. This capacity to articulate decision making across disciplines is a key step in facilitating transdisciplinary management goals. Fundamentally, if a supply chain is not

'well-coordinated from the consumer backward to basic inputs [habitat], then demand signals may not get transmitted properly, most especially signals that might provide the basis for consumer-responsive strategies supporting sustainability'

Peterson and Fronc, 2007.

Understanding the place-based context of extraction in the seafood supply chain is crucial for supply chain management decisions that are made regarding what habitats to protect, and where to allow fishing to take place.

Characteristics of Small-Scale Capture Fisheries

The practical delineation between Small-Scale Capture Fisheries and Large-Scale Capture Fisheries in Europe has been set at a 'Vessel Size' of 12m length (EC, 2006). Vessel size is used to define fishery 'types' in some fisheries. Under this definition, all but one of the Lipsi Fisherman's Association fishing fleet is defined as a small-scale fishing vessel (the one vessel of 12.8m is identical to all the other small-scale fishing vessels in all but length). Within the EU approximately 70,000 (~84%) of the European Union's fleet fall into this Small-Scale Capture Fishery category providing direct employment for an estimated 100,000 people (Guyader et al, 2007). The high numbers of vessels involved in European SSCFs, and their distribution over extended coastlines (Figure 120) makes the monitoring and management of the SSCF fleets extremely complex (Lleonart and Maynou, 2003).

Figure 96. The high numbers of Small-Scale Capture Fishery vessels spread over the islands and coastlines of Greece making monitoring and management a challenge.

While there has been substantial discussion of what constitutes the category of small-scale fisheries, its considerable ambiguity is often passed over (Johnson, 2006). SSCF are generally multi-gear and multi-species, play a large role in supporting household and community livelihoods, and contribute significantly to local and global trade in fish products (Jacquet and Pauly, 2008; Kittinger et al., 2013; Guyarder et al, 2013). They have often been celebrated for their purported limited impact on marine resources (both habitat and assemblage) and their relatively high capacity for employment (EC, 2001; Carvalho et al, 2011). SSCFs in Europe would be categorized as relatively small fishing groups, with a low division of labour, with fish products mostly destined for local sale (Guyarder et al, 2013). In addition to their small size (<12m), SSCF vessels are owner-operated and require relatively low capital investment, making market entry much more accessible, at least in comparison to the Large-Scale Capture Fishery (LSCF) fleet.

In the Mediterranean Sea, SSCF mainly operate on the continental shelf (0-200m depth) in areas that can be reached within a few hours from home ports (Colloca et al., 2004; Tzanatos et al., 2005; Tzanatos et al, 2006; Forcada et al, 2010; Leleu et al, 2014). Characteristically, boats are active throughout the year, or through part of the year and their fishing activity is characterized by a diverse array of gears. A place-based understanding of fishing gears enables the generation of relevant spatial-temporal patterns of effort allocation and the contextualizing of resultant catch (Pelletier and Ferraris, 2000; Colloca et al., 2004).

Understanding the way that fishermen select and change gears in response to changing conditions is an important step for the improvement of fisheries management. It can help to predict the outcome of different management actions and select appropriate management strategies (Salas and Gaertner, 2004, Tzanatos, 2006b), and allows researchers to understand why fishermen target specific habitats using specific gears at particular times of the year; as fishermen react to changes in target species and varying resource availability (Colloca et al., 2004; Fourcada et al, 2010).

In 1985, in Greece, restrictions were placed on recreational fisheries. This legislation, combined with the prohibition of issuing of new professional licenses in 1988 prompted many recreational fishermen to obtain professional licenses, resulting in a sharp increase in the number of registered professional fishermen and fishing vessels within the country (Nireus, cited in Tzanatos et al., 2006b). The result today is a system where many professional license holders do not rely on fishing to make a living. For example, The Lipsi Fisherman's Association has 25 registered fishing vessel licenses, and yet only 8-10 fishing vessels could be considered 'full time' fishers. As such, conflicts within the community over fishing 'entitlement' and the resulting right of extraction / need for sustainable management (of a shared resource) persist (see Stergiou et al, 2002a). Such conflict will remain unless the relative level of dependence of fisherman formally registered to the profession is clarified and the responsibilities for the shared management of the resource socially formalised (Tzanatos et al., 2006b).

Socio-Economic and Ecological Pressures

Globally, SSCF fisheries are affected by both local threats as well as more widespread external pressures, and vulnerability to these pressures threatens the sustainability of both coastal communities (socio-economic system) and coastal habitats (ecological system) (Kittinger et al., 2013). One pertinent example is that emerging global markets incentivize the harvest of valuable species for export (Jaunky, 2011; Box and Canty, 2011) which results in the increased vulnerability of SSCF to volatile price changes driven by international market dynamics (Cinner et al., 2012, Brewer et al, 2012). In addition, climate change may profoundly and species invasions (Galil, 2007; Zenetos, 2010) are affecting the distribution and abundance of key fishery species which alters both the socio-economic and political dynamics of fisheries (Kittinger et al., 2013). At the local scale, threats such as over-exploitation and habitat degradation can affect fisheries resources and habitats, placing at risk the livelihoods, food security, and cultural practices associated with SSCF (Peterson and Fronc, 2007).

In the context of global pressures on fishing stocks e.g. over-capacity of fleets, over-exploitation of stocks, globalization of supply chains (EC, 2009) SSCFs could be in a strategically favourable position to transition to supply chain sustainability in comparison to the LSCF fleet (Guyarder et al, 2013). Much of this advantage relates to the relatively low market entry cost of SSCF fishing gears and the tendency towards static gear fishing methods (e.g. gill nets, trammel nets, pots) that do not degrade the habitat (and thus product provision) upon which the supply-chain depends. Both wider European, and Greek SSCFs, tend to favour the use of static fishing gears which minimize habitat damage and bring fresh, high quality products to the marketplace, differentiating their produce from imported (frozen and tinned) alternatives. In addition, fishing costs (especially fuel) are reported to be lower amongst SSCFs using passive gears (Pauly et al., 2002).

Data Paucity and Overfishing

In Greece, as is common across the Mediterranean, small-scale fishing activities are dispersed along the extensive coastline and across the multiple island groups that characterise the country. This dispersion creates practical difficulties to obtaining long term data (Isaac et al, 2008; Béné et al., 2011) due to the numerous places and vessels that would need observation. For this reason, fisher’s participation in interviews and landing observation is necessary for the generation of information as to the variations within the fishery in both time and place. The first element of contextualizing this stage of the SSCF SSCM is therefore in characterising the fishery.

Official fisheries landings data has limited accuracy (Pauly and Froese, 2012) with false statistics known to distort data sets that result in over-reporting (Watson and Pauly, 2001) and under-reporting (Pauly and Maclean, 2003). In fact, it was recently estimated that over the last six decades, at least 50% more fish have been extracted from the ocean than official data has, to date, reported (Pauly and Zeller, 2016). The Mediterranean and Black Sea fisheries have been identified as one region that has fallen into the 'under-reporting' of landings category. A major component of this underestimation has been linked to the fact that these statistics have not included discarded, subsistence, recreational and other non-reported catches. These are generally referred to as illegal, unreported and unregulated catches (IUU) and are primary target of European Union policy (Moutopoulos et al, 2015).

Overfishing at higher trophic level "fishing down marine food webs" (Pauly et al., 1995; Pauly et al., 2005) can cause unbalanced food-webs, which can lead to assemblage 'cascade effects' (Pinnegar et al, 2000; Dulvy et al, 2004) or habitat 'regime shifts' (Rocha et al., 2015; Levin et al., 2015). Such problems are often associated with the loss of apex predators such as sharks (Myers et al., 2007), but can also be witnessed at lower trophic levels, for example with sea-urchin overgrazing seagrass (Eklöf et al., 2008). In addition, fecundity generally increases with age simply as a function of body size because a larger body cavity allows development of larger ovaries. Larger females therefore contribute substantially to stock productivity and stability in ways considerably different from smaller females (Hixon et al., 2014).

Data-poor areas, such as the Greek waters (Pilling et al, 2009) are therefore areas in need of immediate attention. The multi-species and multi-gear nature of the fisheries in Greece, along with the vast coastline and highly dispersed vessels make monitoring difficult (Tzanatos et al, 2006a, Tzanatos et al, 2006b). Recent attempts have been made to reconstruct historic fisheries catches (sensu Zeller et al., 2007) in Greece for the period 1950-2010 (see Moutopoulos et al., 2015).

Results from this work indicate that total reconstructed catches (including discarded catches) within Greek waters accounted for over 9.8 million tons from 1950-2010, which is 57% higher than the 6.2 million tons officially reported in Greek national statistics for their waters. This new data is shifting the management 'baseline' (sensu Pauly et al, 1995) for sustainability of stocks. Whilst unpopular with some industry leaders, this method has provided a more realistic assessment of the current status of Greek fisheries.

This case-study of the Lipsi SSCF provides place-based evidence for more sustainable management of this particular Small-Scale Capture Fishery, particularly since Lipsi is an island and the fishers maintain their primary activity in coastal margins and assemblage extraction from habitats can be assumed to be confined to within 12 nautical miles [often less] of the home port (Guyarder et al, 2013). Such confined spatial delimitation provides opportunities for both Marine Spatial Planning and for Sustainable Supply Chain Management of this particular 'place' (even if what is reported for Lipsi may not reflect the patterns for other areas of the Greek coastline).

7.2 Aims and Objectives

This chapter focuses on establishing data pertaining to the extractive characteristics of the Lipsi fishery by investigating:

1. How, when and where are the species [products] extracted by the Lipsi fishery? Where are the fishing grounds and what are the habitats targeted? (*characterise the industry*)
2. What are the species (products) extracted by the Lipsi Small-Scale Capture Fishery? (*landings and bycatch)*
3. What are the longer-term trends in species diversity and abundance as recalled by local fishers (in living memory) in the Small-Scale Capture Fishery? (*environmental impact*)

Objectives

1. To characterise the Lipsi Small-Scale Capture Fishery by identifying what fishing gears are being deployed. Identifying if there is a seasonal pattern to deployment, and identifying where gear is deployed.
2. To determine if specific species [products] are targeted for extraction.
3. To establish if the nature of the fishery (variety and abundance of products) has changed over time in line with the documented overfishing of Hellenic waters from 1950-2001(see Stergiou, 2005).

7.3 Materials and Methods

Multiple methods were pursued to obtain a richer picture of the Lipsi SSCF (Figure 121). The fisheries data presented in this chapter was recorded in partnership with collaborating fishermen from the Lipsi Fisherman's Association. Time of extraction (temporal data), catch per unit effort (CPUE) (species abundance), species composition within catch (species richness) and catch maturity (landed species total length) were quantifiable from Fishery Landings Data (FLD).

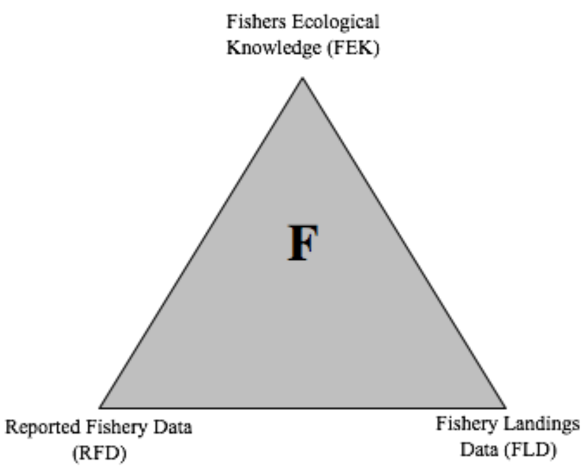


Figure 97. For a richer understanding of the Lipsi Small-Scale Capture Fishery, a triangulated approach has been adopted incorporating Fishers Ecological Knowledge (FEK), Reported Fisheries Data (RFD) and Fishery Landings Data (FLD).

This represents directly 'measured' data by the observer. In contrast Reported Fishery Data (RFD) includes place and depth of extraction (spatial data) and gear use. This represents 'reported' data by the fisher. Together these data characterise the current elements of the Lipsi fishery. To understand this current position in relation to its historical context, use of Fishers Ecological Knowledge (FEK) was included. This approach enabled the fishery to be articulated in relation to its perceived historical context.

Study Sites

The prevailing climate of Lipsi determines the weather patterns that directly affect the ability of fishers to conduct fishing activity across the Lipsi seascape (Figure 122).

Figure 98. The Lipsi Seascape. Thirty-nine name fishing sites were identified around the island from discussion with fishers during landing surveys.

From the beginning of the summer season in June, to the end of the autumn season in November, there is a notable change is fisher's gear deployment moving from trammel and gill nets in the summer to a focus towards longlines and squid 'jigs' as the autumn arrives. This relates to climatic restrictions, as well as both ecological (e.g. seasonal availability of fish) and socio-economic (e.g. seasonal demand for fish) factors. Fishing effort declines from November and into the Winter season (December, January, February). Fishing begins in earnest again after the Easter festival once fishing vessels have been serviced in March.

On Lipsi, rainfall generally peaks in the winter months, coinciding with periods of unsettled weather with few calm days and rarely any consistent wind direction (Table 38).

Table 25. Climate of Lipsi; including rainfall, temperature, wind direction and number of calm days. *Wind data used was taken from a database of worldwide observations taken from 1850 – 1974 (sailingissues.com) ** No clear dominance in wind direction

Season	Spring			Summer			Autumn			Winter		
Month	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb
Rain (mm)	76	32	18	3	0	0	13	45	88	152	153	103
°C (mean)	12.6	16.1	19.8	24.0	27.0	27.0	23.9	19.9	15.9	13.1	11.0	11.1
Wind*	N	SE	NW	NW	NW	NW	NW	NW	SE	**	S	N
Calms	6	7	10	9	0	1	6	9	4	4	2	1

This results in limited and somewhat opportunistic fishing activity. In contrast, during the summer months the “Meltemi” wind creates a period of consistent strong winds from the north-west, with very few calm days but little rainfall. Fishing during this period is generally restricted to the sheltered south-eastern coasts.
For this chapter, all data collection pertaining to the active fishery (Reported Fishery Data and Fishery Landings Data) was conducted portside, in collaboration with participating fishers.

Informal interviews documenting Fisher’s Ecological Knowledge (FEK) was also conducted in the port area, or in one of the cafés or houses adjacent to the port in the surrounding village (Figure 123). On Lipsi between 8-10 fishers can be considered 'full time' fishers, but 21 fishers were involved in RPD data collection on Lipsi. This included fishers from the neighbouring islands of Kalymnos and Arki who occasionally conducted their fishing from the island of Lipsi during the summer months.

Figure 99. The Port of Lipsi is the main port on the island. The village of Lipsi is built around the port.

7.3.1 Reported Fishery Data

Reported fisheries data was collected daily where logistically possible during field time, between the hours of 07:00 and 11:00 throughout the Spring, Summer and Autumn seasons (from March-November 2014). Participants for interviews were initially selected via key informants and the process was largely one of community engagement and participation through informed choice. Information was provided to the participants concerning the subject area to which the study relates and informed consent was obtained (see Ethics Appendix)

Fishers were approached portside and enquiry was made as to the primary gear type used on the fishing trip, the depth at which the gear was deployed and the preferred fishing habitat type (Figure 124). 'Wind Direction' and 'Wind Strength' was also recorded from a Windguru™ Custom Spot (User: RJLilley, Site: Lipsi). The date, the name of the captain and the name of the boat were also recorded for reference.

Reported fishery data allowed for key characteristics of the fishery to be recorded to help *characterise the fishery*. Most fishers were happy to answer these questions, but many were unwilling for their fish to be handled (i.e. measured and counted) and thus became ineligible for full participatory FLD.

Figure 100. Fishers were approached portside to record Reported Fishery Data and to conduct Fishery Landings Data with participating fishers.

7.3.2 Fishery Landings Data

In addition to the RFD, five fishers participated in FLD, enabling observers to count and measure all species landed. Occasional 'on board' observation of fishing activity was conducted enabling the relative incidence of by-catch to be observed (Figure 125). The frequency of such by-catch incidences was negligible with the clear majority of fish that were caught being landed (>95%). For those species that were returned, it was noted that for shallow water (<50m) fishing, most non-target species were returned unharmed. However, for species returned from depth (>50m), the pressure change was often great enough to have proved lethal.

Figure 101. Non-target species (such as juveniles) could be returned to the ocean unharmed.

Fisheries landings provides robust quantitative data relating to *landings and bycatch*, specifically seafood diversity, abundance and maturity. Individual fish species were counted, and their Total Length (TL) measured on a fish measuring board. Fish were identified on the portside, if a species identity was unknown a photograph was taken for later identification.

7.3.3 Fishers Ecological Knowledge

Without a quantitative baseline for the Small-Scale Capture Fishery a qualitative approach must be adopted to assess if the fishery is developing or degrading. A semi-structured interview was conducted (with the assistance of a local translator) with seven fishers using a prepared questionnaire. The questions pertained to fishers' experience, their perception regarding temporal and spatial changes in the condition of fish stocks, identification of over exploited species and the need for further fishery management measures (see Appendix). Focus group techniques might be biased toward the opinion of a few outspoken or politically powerful participants (Morgan, 1993) and therefore all interviews were conducted in private to minimize the effects of other fishers' presence on the answers given. Fishers were informed on the purpose of the research and consent was obtained from participants before conducting interviews (see Appendix). This element of the research was conducted to try to contextualise the perceived changes that the fishery had undergone over the last 50 years, and therefore the trajectory of the supply chain either towards, or away from, sustainability.

The first interview was conducted with the head fishermen who acted as a key informant. Six further fishers were then interviewed following the snowballing technique (Davis and Wagner, 2003). All seven fishers interviewed were professional fishermen, working full time, using a variety of small-scale fishing gears to target fish in the local area. The Semi-Structured Interview was used to elicit Fishers Ecological Knowledge pertaining to three broad topics:

1. Perceived Temporal Changes in Seafood Supply
2. Perceived Spatial Changes in Seafood Supply
3. Fishers Suggested Management Measures.

Generally, the interviews focussed on what were the perceived negative changes in the conditions of local fish stocks, particularly regarding lower fish abundances and changes in catch composition. Additionally, fishers' opinions were explored on the perceived presence of specific overexploited species and their perceived presence of overfished sites (fishing grounds). The concept of for changes in seafood preferences was explored in response to the changing seafood supply as were fishers' ideas on potential management measures that might improve / recover seafood supply back to its former capacity. For full details on the Semi-Structured Interview see Appendix.

7.4 Data Analysis

Size data

For the size data, a distinction had to be made between juvenile and adult fish abundances. Fish were classified using maturity data from FishBase (when available) or using the commonly applied 'rule of thumb' that individuals smaller than one-third of the maximum species' length were juvenile (Nagelkerken & van der Velde 2002, Unsworth et al., 2008). For species with a maximum length >90 cm, individuals were recorded as juveniles when <30 cm long. All maximum length data were obtained from FishBase (Froese & Pauly 2016).

Abundance data

Whole catch assemblage data was categorised into 1 of 4 depth ranges (1-25m, 26m-50m, 51,75m, and 76-100m). No fisher reported fishing deeper than 100m highlighting the shallow water, coastal nature of the fishery. Whole catch assemblage data was also categorised into 1 of 4 groups of fishing gear (trammel, gill, longline and handline), 1 of 3 groups of for season (spring, summer, autumn) and 1 of 4 groups of habitat association (seagrass, rocky-algal reef, sand, coralline). These simple categorisations were based on the gears fishers used and habitats that fishers had reported fishing over as the seasons progressed. All mean summary statistics were calculated with their standard error. ANOSIM and SIMPER were performed on root transformed data. This was used to analyse any differences in fish abundance and species richness between different habitats, gears and seasons.

ANOSIM results are presented with the *p*-value (significance levels) and R-value (the strength of the factors on the samples). Analysis of differences in reported fish assemblage structure between habitat type was conducted using multi-variate non-metric multidimensional scaling ordination (MDS) and Bray-Curtis cluster analysis using the computer package PRIMER 7 (Clarke & Gorley 2015). The Bray-Curtis similarity index was applied on square-root transformed data (to down-weigh the influence of rare and extremely abundant species) and to generate a rank similarity matrix, which was then converted into an MDS ordination. To check on the adequacy of the low-dimensional approximations seen in cluster and MDS the use of PRIMER 7 enabled clusters to be superimposed upon the MDS ordination (Clarke & Gorley 2015). A 2-way analysis of similarities (ANOSIM) was used to investigate differences identified from MDS and CLUSTER (Clarke & Gorley 2015).

Fishing pressure

To enable clear presentation of fishing pressure data a Heatmap Plugin for QGIS 2.14 (Essen) using Kernel Density Estimation was used to create a density raster of an input point vector layer. This allowed a map of fishing pressure to be generated. The Coordinate Reference System used was WGS84 / UTM zone 35N (EPSG:32635). Cell size was set at 0.001, Radius 0.007. Kernel shape is Quartic (biweight). The density was calculated based upon point location data collected from fishers during RFD data collection.

Wind data

Wind strength and wind direction were calculated with their mean and directional statistics. These have been presented as a wind rose alongside the fishing pressure map. A wind rose is a chart that gives a view of how wind speed and/or wind direction are distributed at a specific place over a specific time period.

7.5 Results

7.5.1 Reported Fishery Data

139 surveys were completed spanning three seasons (March to November). 41 surveys were conducted in Spring (Mar, Apr, May) 59 surveys in Summer (Jun, Jul, Aug) and 39 surveys in Autumn (Sep, Oct, Nov). Trammel nets were the gear of choice on 88 occasions, Gill nets on 32 occasions, Longlines on 15 occasions and handlines on 4 occasions. The mean [and median] depths for gear deployment were; Trammel 19.0m [13.0m]; Gill 16.3m [13.0m], Longline 57.5m [52.5m] and Handline 11.5m [11.5m] respectively. *Posidonia oceanica* seagrass habitat was targeted on 73 occasions, Rocky-Algal habitat on 41 occasions, Coralline formations on 17 occasions and un-vegetated sandy bottom on 8 occasions. The following section characterises the multi-gear and multi species-nature of the Lipsi Small-Scale Capture Fishery and establishes patterns by season, gear, depth and habitat.

Extraction patterns by season

Fishery landings data revealed mean species richness to be highest in Spring 10.20 (±0.47), followed by a decline in Summer 7.22 (±0.36) and further decline in Autumn 5.97 (±0.39) (Figure 126).

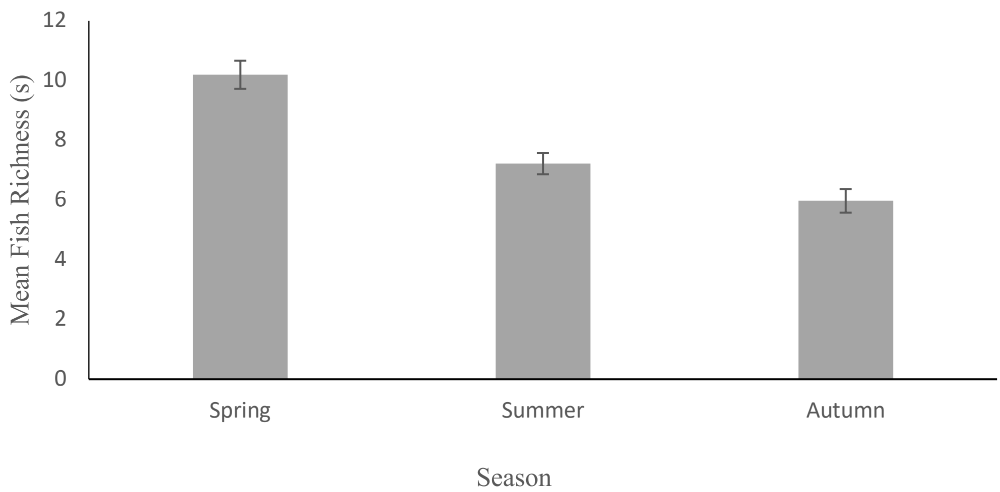


Figure 102. Mean (±SE) species richness per fishing trip per season (across depths, gears and habitats)

Fishery landings data revealed mean species abundance to be highest in Spring 46.76 (±4.37), followed by a decline in Summer 40.10 (±4.30) and further decline in Autumn 37.59 (±5.85) (Figure 127).

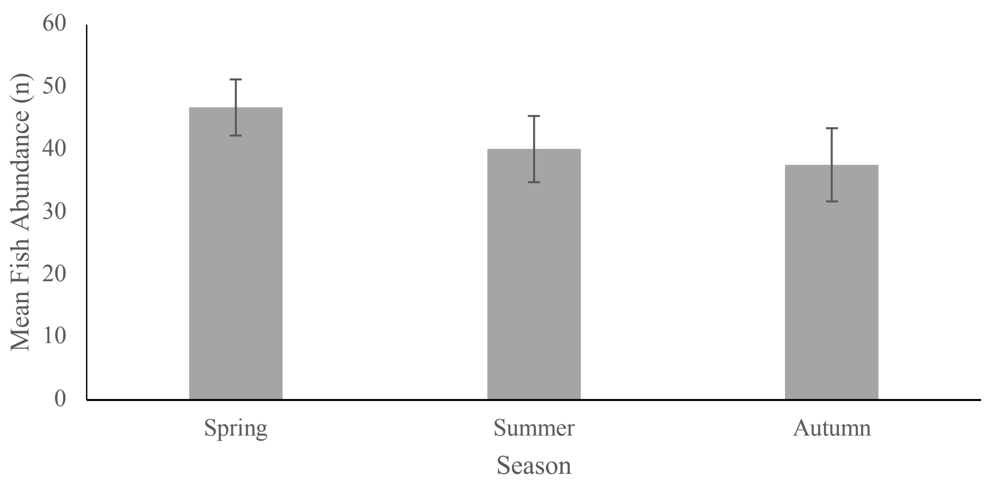


Figure 103. Mean (±SE) species abundance per fishing trip per season (across depths, gears and habitats)

ANOSIM confirmed that the species assemblages from recorded landings differed significantly between seasons (Global R = 0.282, p = 0.01). Noticeably greater differences were identified between Spring and Autumn (R =0.396, p=0.01) and Summer and Autumn (R =0.345, p = 0.01) than between Spring and Summer (R = 0.116, p =0.01).

Superimposed Bray-Curtis clusters onto the MDS ordination (Figure 104) showed differentiation between seasons. Although there was some separation between Spring and Summer, the clustering of assemblages landed between Spring/Summer and Autumn show high dissimilarity. The low similarity levels of the overlayed clusters (10%) illustrated that differences between habitat assemblages were present even at low resolutions.

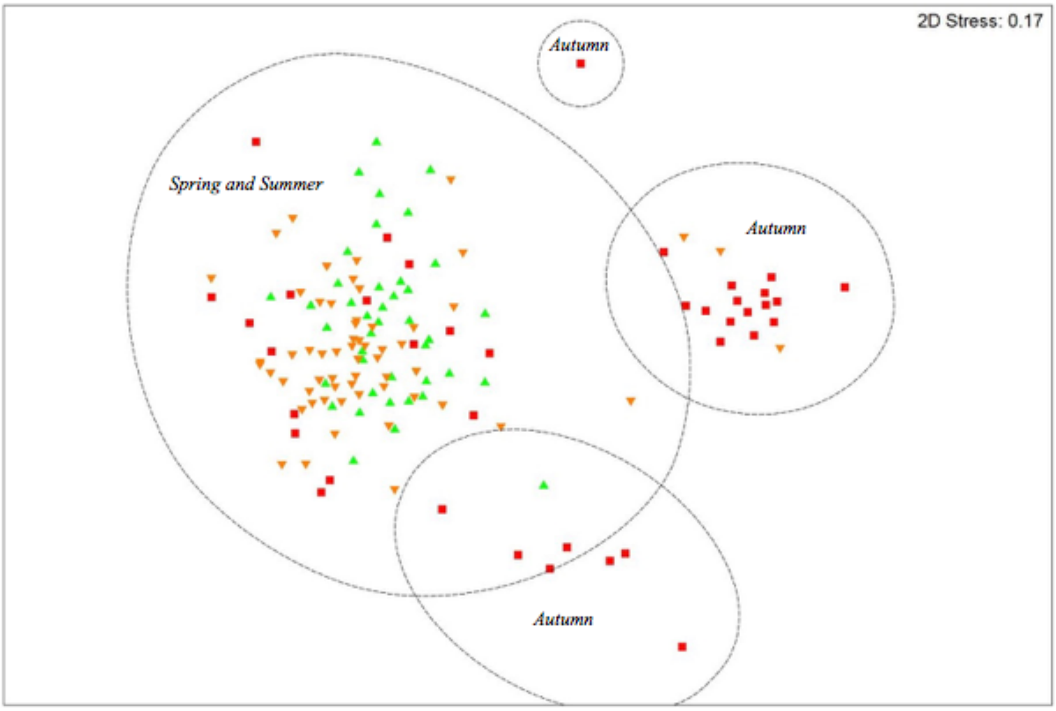


Figure 104. nMDS plot showing clustering of species landed by season. Spring (▲) and Summer (▼) showing similar landed species assemblages. Autumn (■) was markedly different.

SIMPER analysis revealed average similarity of 37.67 in the Spring, 38.10 in the summer and 16.74 in the Autumn. This data highlighting the similarity in species assemblage from landings conducted Spring and Summer seasons, in comparison to the Autumn.

Group similarities are presented for the highest contributing species with a cut-off percentage of 75.0% (Table 40).

Table 26. Highest assemblage similarities for each season and the relative contributions of the highest contributing species. *D.macroptalmus = Dentex macroptalmus*

Species	Mean Abundance	Mean Similarity	±StDev Similarity	Contribution %	Cumulative %
Spring					
Average similarity: 37.67					
Siganus luridus	4.24	10.38	1.37	27.55	27.55
Sparisoma cretense	2.69	5.98	1.22	15.89	43.43
Oblada melanura	3.20	5.40	0.59	14.34	57.77
Scorpaena scofa	2.03	3.82	0.86	10.15	67.93
Scorpaena porcus	1.59	2.69	0.70	7.15	75.07
Summer					
Average similarity: 38.10					
Siganus luridus	5.01	14.93	1.13	39.18	39.18
Sparisoma cretense	4.04	12.16	1.32	31.91	71.09
Oblada melanura	1.81	2.44	0.45	6.41	77.50
Autumn					
Average similarity: 16.74					
Serranus cabrilla	2.20	3.22	0.39	19.24	19.24
D. macroptalmus	2.09	2.63	0.33	15.68	34.92
Siganus luridus	2.12	2.53	0.34	15.11	50.03
Pagellus erythrinus	1.50	1.98	0.37	11.82	61.85
Loligo vulgaris	1.56	1.74	0.27	10.41	72.26
Sparisoma cretense	1.06	0.77	0.23	4.58	76.84

The species similarity data highlights the transition that takes place in the fishery between the Summer and Autumn months. The Dusky Spinefoot (*Siganus luridus*), the Meditteranean Parrotfish (*Sparisoma cretense*), the Saddled seabream (*Oblada melanura*) dominate the catch in the Spring and Summer respectively, with the Largescale scorpionfish (*Scorpaena scorfa*) and the Black scorpionfish (*Scorpaena porcus*) making notable contributions. However, in Autumn, the most common species are the Comber (*Serranus cabrilla*), the Large-eye dentex (*Dentex macropthalmus*), and the Common Pandora (*Pagellus erythrinus*, which are associated from the landing of fish from deeper waters (see above). The omnipresent Dusky Spinefoot (*Siganus luridus)* continues to be landed in high numbers from the shallow waters, with the Common squid (*Loligo vulgaris*) making a notable contribution to the Autumn catch. This data highlights the inconsistent (seasonal) nature of product supply which is essential knowledge for managing the demand and promotion of seafood products from the Lipsi Small-Scale Capture Fishery supply chain.

Extraction patterns by fishing gear

The use of four different fishing gears (Figure 129) were recorded by fishers over the studied fishing season (Spring to Autumn). Trammel nets and Gill nets were generally deployed overnight with soak times of 12.7 (±3.3) hours and 13.9 (±3.4) hours respectively. In contrast longlines were generally deployed and then left for a short period; 3.3 (±0.8) hours, before being collected the same day. Similarly, evening fishing trips to "jig for squid" only lasted for short periods; 3.9 (±0.9) hours.

In both the Spring and Summer, the Trammel net was the favoured gear type being deployed in over three out of four (78.0% and 78%) of fishing trips in both seasons, with a marked decline to just over one in four (25.6%) of all deployments in the Autumn. In contrast Longlining was absent in Spring, before minimal deployment in Summer (1.7 %) and a marked increase to over one in three deployments in Autumn (35.9 %). Handlining ("Jigging") for squid was exclusively conducted in Autumn accounting for just over one in ten deployments (10.3 %). The most consistent gear was the Gill net which was used consistently across all seasons (22.0 %, 20.3 % and 28.2 % for Spring, Summer and Autumn respectively). The variable deployment of fishing gears across seasons can be expected to have a direct effect of the abundance and richness of species caught and thus entering the SSCF supply chain.

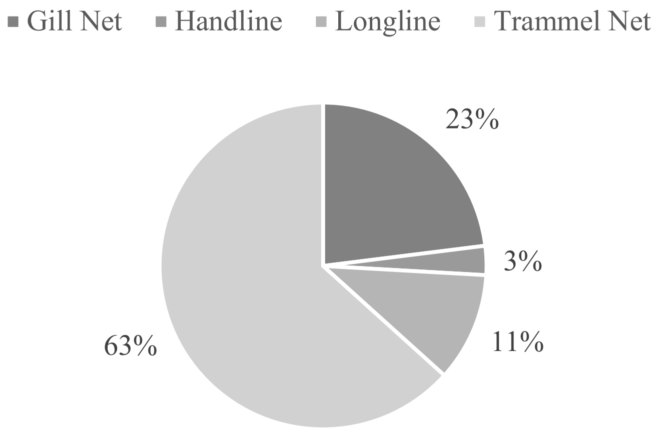


Figure 105. Relative fishing effort by gear type. The majority of fishing was conducted with fishing nets (74%) as opposed to fishing lines (26%).

Fishery landings data revealed mean species richness of landed fish to be highest with Trammel nets 8.28 (±0.35). This was followed by Gill nets 7.38 (±0.52) and Longlines 6.87 (±0.46). Handlines exhibited the lowest species richness 2.25 (±0.63) (Figure 130).

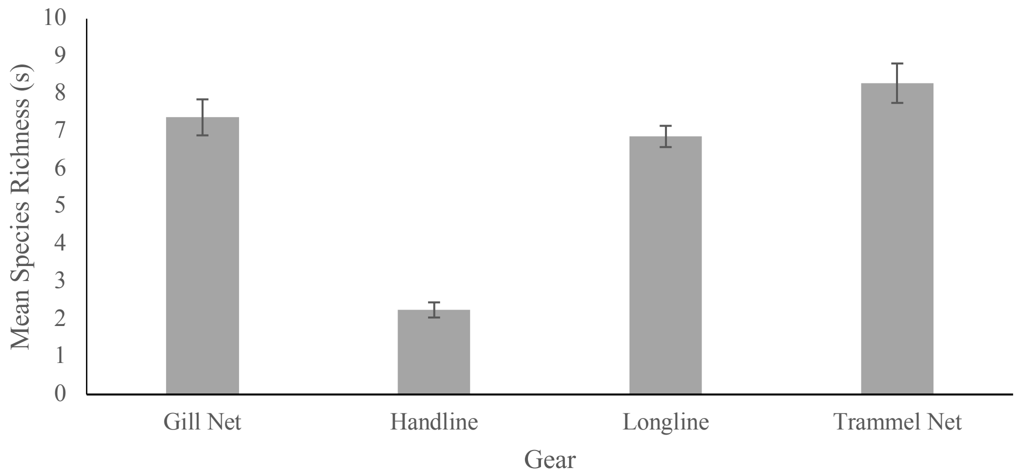


Figure 106. Mean (±SE) species richness per fishing trip for fishing gear (across seasons and habitats)

Fishery landings data revealed mean species abundance of landed fish to be highest with Longlines 76.20 (±7.83) fish per trip. This was followed by Gill nets 40.03 (±6.52) and Trammel nets 37.38 (±2.98). Handlines exhibited the lowest species abundance at 9.00 (±4.08) fish per trip (Figure 131).

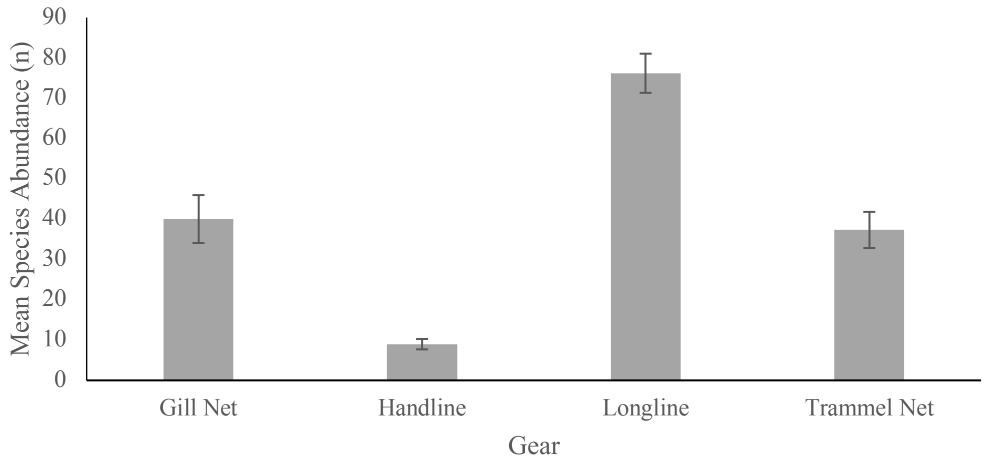


Figure 107. Mean species abundance (±SE) per fishing trip for each type of fishing gear (across seasons and habitats)

ANOSIM confirmed that the species assemblages from recorded landings differed significantly between gears (Global R = 0.516, p = 0.01). Handline and Longlines showed complete difference in catch assemblages (R = 1.00, p = 0.01), and whilst significant, Gill and Trammel nets showed the least difference in catch assemblages (R = 0.204, p = 0.01). Both net types showed significant differences in relation to other gear types: Trammel and Longline (R = 0.873, p = 0.01), Trammel and Handline (R = 0.868, p = 0.01) and Gill and Longline (R = 0.867, p = 0.01), Gill and Handline (R = 0.710, p = 0.01).

Superimposed Bray-Curtis clusters onto the MDS ordination (Figure 132) showed differentiation between gears. Although there was some separation between Trammel and Gill nets, it is the clustering of longline and handline that shows the most dissimilarity from the net fishery, and from each other. The low similarity levels of the clusters (10%) illustrated that differences between gear types were present at low resolutions.

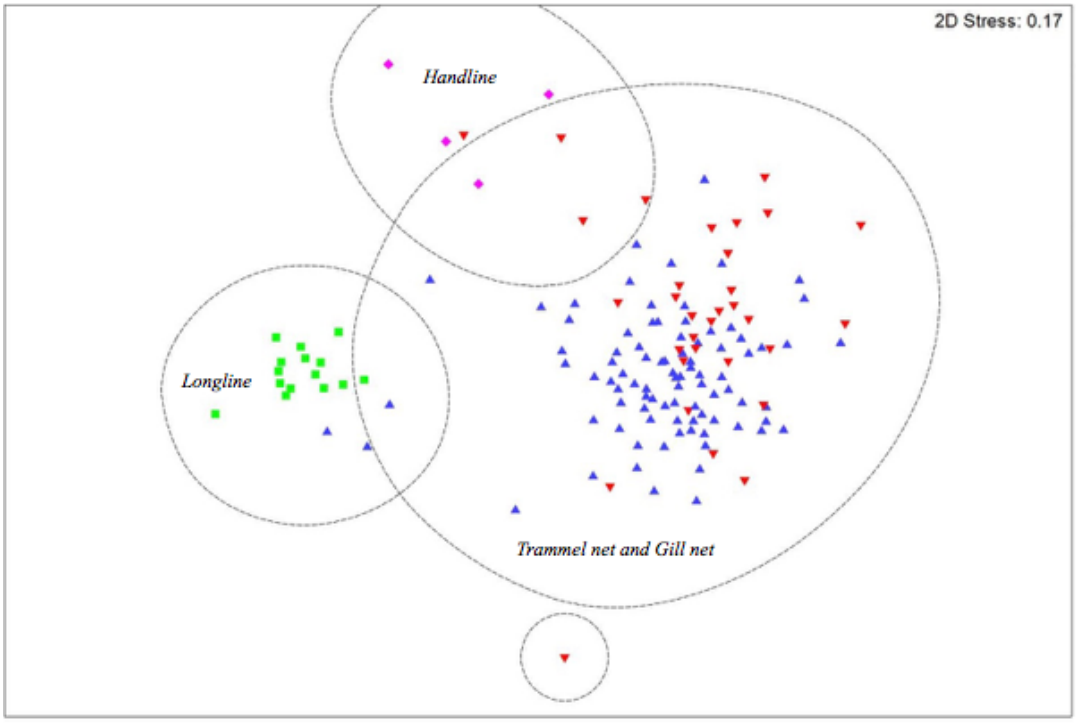


Figure 108. nMDS configuration with superimposed Bray-Curtis similarity clusters at the 10% level for sample comparison of fish species abundance, by gear: Trammel net (▲), Gill net (▼), Longline (■) and Handline ( )).

SIMPER analysis revealed average similarity of 37.67 in the Spring, 38.10 in the summer and 16.74 in the Autumn. This data highlighting the similarity in species assemblage from landings conducted Spring and Summer seasons, in comparison to the more diverse fishery of Autumn. Group similarities are presented for the highest contributing species with a cut-off percentage of 75.0% (Table 40).

The species similarity data highlights how fishers use different gears to target different species. Such targeting of species will occur in response to both seasonal market forces (demand) and seasonal habitat provision (supply). Inconsistency in both product supply and product demand is a challenge for the sustainable management of the Lipsi SSCF supply chain. However, knowledge of what gears capture what species, and when, can inform decisions about how and when to fish for seafood products and go some way to managing product supply to the marketplace.

The data reveals that the Dusky Spinefoot (*Siganus luridus*), the Mediterranean Parrotfish (*Sparisoma cretense*), the Largescale scorpionfish (*Scorpaena scorfa*) and the common cuttlefish (*Sepia officinalis*) constitute the major contributors to Trammel net catch. The Dusky Spinefoot (*Siganus luridus*) and Mediterranean Parrotfish (*Sparisoma cretense*) also make major contributions to Gill net landings, but they are joined by the more pelagic Saddled seabream (*Oblada melanura*) and Barracuda (*Sphyraenidae*).

For longline deployment, the most common species are the Comber (*Serranus cabrilla*), the Large-eye dentex (*Dentex macropthalmus*), and the Common Pandora (*Pagellus erythrinus*). The Common squid (*Loligo vulgaris*) is the only species caught by handline, which is specifically deployed in the fishery to 'jig' for squid.

Table 27. Table showing the highest assemblage similarities for each gear by season and the relative contributions of the highest contributing species. *D.macroptalmus = Dentex macroptalmus.*

Species	Mean Abundance	Mean Similarity	±StDev Similarity	Contribution %	Cumulative %
Trammel net					
Average similarity: 36.08					
Siganus luridus	5.05	14.45	1.20	40.05	40.05
Sparisoma cretense	3.53	9.23	1.17	25.58	65.63
Scorpaena scrofa	1.63	2.69	0.65	7.44	73.07
Sepia officinalis	1.51	1.87	0.45	5.18	78.25
Gill net					
Average similarity: 30.09					
Oblada melanura	4.29	9.94	0.78	33.03	33.03
Siganus luridus	3.37	7.74	0.90	25.73	58.76
Sparisoma cretense	2.49	4.84	0.71	16.08	74.83
Sphyraenidae	1.15	1.19	0.34	3.97	78.80
Longline					

Average similarity: 66.31					
Serranus cabrilla	5.75	23.61	4.11	35.61	35.61
D. macroptalmus	5.93	22.35	2.05	33.71	69.32
Pagellus erythrinus	3.73	13.31	2.17	20.07	89.38
Handline					
Average similarity: 44.42					
Loligo vulgaris	7.52	44.42	2.63	100.00	100.00

Extraction patterns by depth

Fishers reported fishing at depths of up to 100m around Lipsi island and at locations never more than 1km distance from the shore. This data emphasises the coastal and place-based nature of the fishery. Reported depths were split into four depth categories; 1m-25m, 26-50m, 51-75m and 76m-100m. Anecdotal evidence from informal discussions with fishers suggests fishing is conducted around the island at depths of up to 160m, but no such fishing activity was reported in this data set. Fishers targeted the shallow waters (1m-25m) most frequently (73%) of occasions, with declining fishing effort in deeper waters (Figure 133).

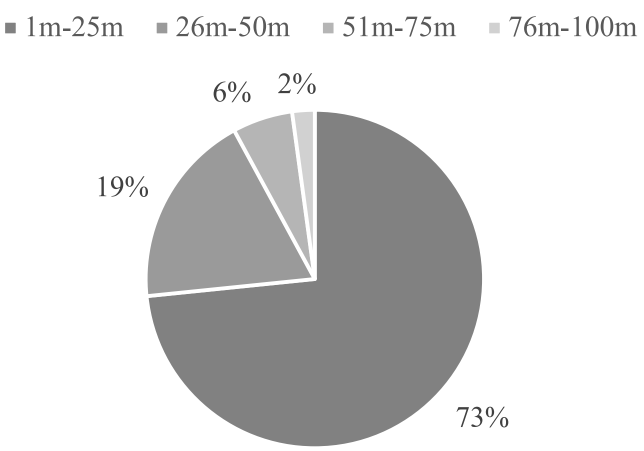


Figure 109. Relative fishing effort by depth range. Most frequently fishing effort was targeted towards shallow waters (<50m)

The targeting fishing effort to the shallower waters could be indicative of the targeting of specific habitat types that occur at shallow depths e.g. *Posidonia oceanica* seagrass meadows which occur between 1m-50m and would thus could be a present in 92% of the recorded deployments.

Fishery landings data revealed mean species richness of landed fish to be highest between 26m-50m depth, with 8.04 (±0.47) fish per trip. This was followed by 1-25m and 76-100m at 7.76 (±0.54) and 7.75 (±0.49) species respectively. The lowest species richness of landed fish was from between 51m-75m depth range at 6.63 (±0.27) species (Figure 134).

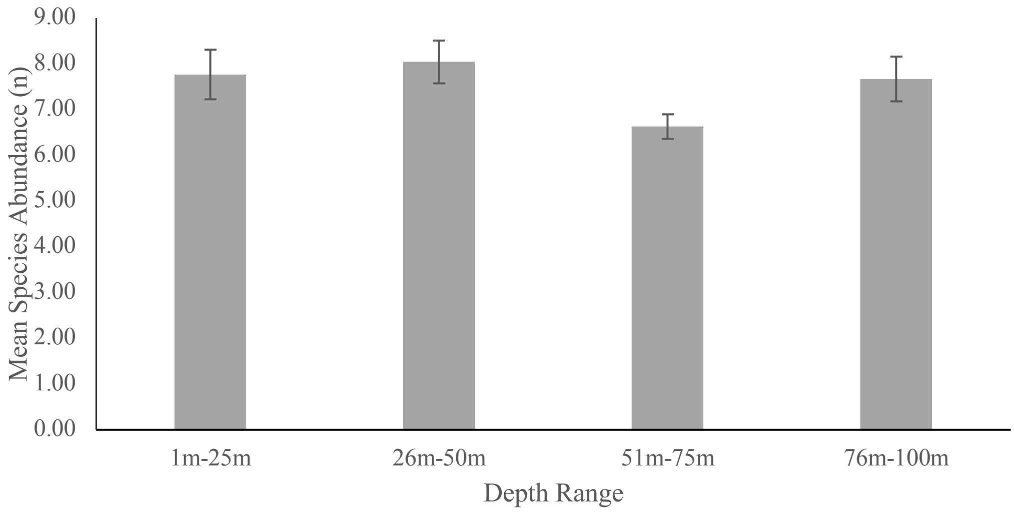


Figure 110. Mean (±SE) species richness per fishing trip per depth range (across seasons, habitats and gears).

Fishery landings data revealed mean abundance of landed fish to be highest between 51m-75m depth, with 67.63 (±7.10) fish per trip. This was followed by 26m-50m and 76-100m at 46.00 (±4.98) and 43.67 (±4.58) individuals respectively. The lowest abundance of landed fish was from between 1m-25m depth range at 38.05 (±5.05) species (Figure 135).

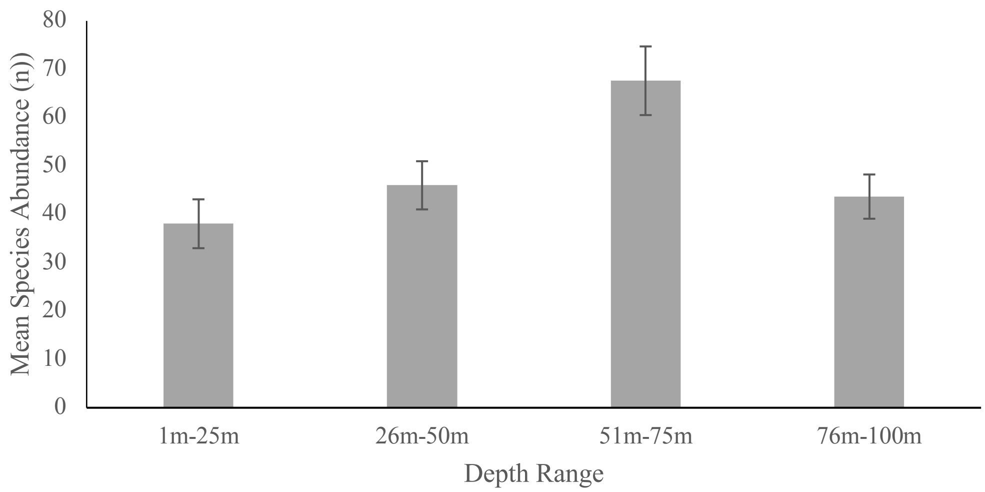


Figure 111. **Mean (±SE) fish abundance per fishing trip per depth range (across seasons, habitats and gears).**

ANOSIM confirmed that the species assemblages from recorded landings differed significantly between depths (Global r = 0.414, p = 0.01). The greatest depth dissimilarities in assemblages were recorded between the shallow 1-25m depth range, and the deep 51-75m (R = 0.809, p = 0.01) and 76m-100m (R = 0.851, p = 0.03) depth ranges respectively. In comparison, no significant differences were elicited between the deep 51-75m and the 76m-100m depth ranges (R = 0.148, p = 0.255). There was a significant difference between the 26-50m and 51-76m depth ranges (R = 0.112, p = 0.039).

Superimposed Bray-Curtis clusters onto the MDS ordination (Figure 136) showed differentiation between depth in the marine environment. Although there was some separation of the 1m-25m depth category, the majority of landings recorded from 1m-50m depths showed high similarity in species assemblages. There was some cross over in species assemblage in the 25m-75 depth range but generally depths greater than 50m (showed high clustering showing species assemblages to be highly consistent. The low similarity levels of the overlayed clusters (20%) illustrate that differences between habitat assemblages were present at low resolutions.

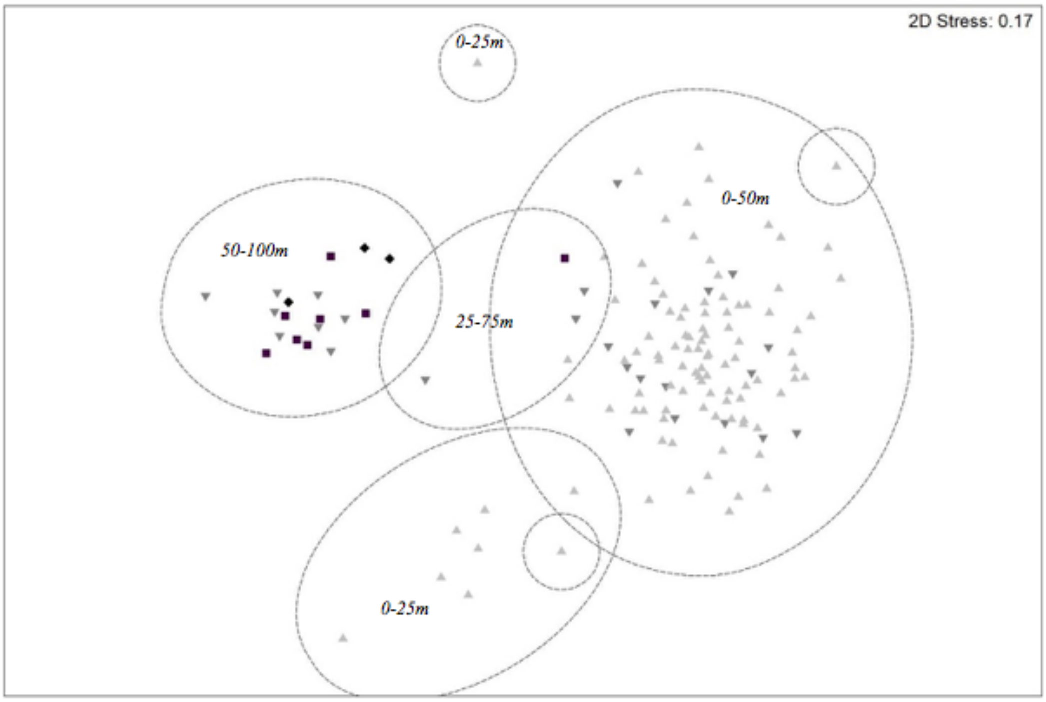


Figure 112. NMDS configuration with superimposed Bray-Curtis similarity clusters at the 10% level for sample comparison of fish species abundance, by depths: 1m-25m (▲), 26m-50m (▼), 51m-75m (■) and 76m-100m ( ).

SIMPER analysis revealed average similarity of 32.92 in the 1m-25m depth range, 22.72 in the 26m-50m depth range, 47.38 in the 51m-75m depth range and 55.47 in the 76m-100m depth range. This data highlighting the higher richness in species assemblage from landings conducted in the 26m-50m depth range, and the low richness of species recorded from landings deeper than 75m. Group similarities are presented for the highest contributing species with a cut-off percentage of 75.0% (Table 41).

Table 28. Highest assemblage similarities for each depth range and the relative contributions of the highest contributing species. *D.macroptalmus = Dentex macroptalmus*

Species	Mean Abundance	Mean Similarity	±StDev Similarity	Contribution %	Cumulative %
1-25m					
Average similarity: 32.92					
Siganus luridus	4.63	12.57	1.12	38.18	38.18
Sparisoma cretense	3.19	7.63	0.97	23.18	61.35
Oblada melanura	2.19	3.10	0.49	9.43	70.78

Scorpaena scofa	1.26	1.76	0.51	5.33	76.11
26-50m					
Average similarity: 22.72					
Siganus luridus	3.06	5.26	0.54	23.14	23.14
Sparisoma cretense	2.37	4.07	0.61	17.91	41.05
Scorpaena scofa	1.56	2.37	0.57	10.41	51.45
Serranus cabrilla	1.93	2.33	0.36	10.27	61.72
Pagellus erythrinus	1.56	1.97	0.38	8.69	70.41
D.macroptalmus	1.62	1.44	0.25	6.33	76.74
51-75m					
Average similarity: 47.38					
Serranus cabrilla	4.85	17.56	1.49	37.06	37.06
D. macroptalmus	5.20	16.82	1.01	35.49	72.55
Pagellus erythrinus	2.51	7.13	1.00	15.04	87.59
76m-100					
Average similarity: 55.47					
Serranus cabrilla	5.96	23.29	6.75	42.00	42.00
Pagellus erythrinus	4.34	17.85	14.34	32.17	74.14
Mullidae sp.	3.58	7.02	0.58	12.65	86.82

The species similarity data highlights the heterogeneous distribution and a transition in the species recorded with depth in the coastal zone. The Dusky Spinefoot (*Siganus luridus*), the Meditteranean Parrotfish (*Sparisoma cretense*), the Saddled seabream (*Oblada melanura*) and the Largescale scorpionfish (*Scorpaena scorfa*) dominate the catch in the 1m-50m depth range. In deeper waters (>50m) the most common species are the Comber (*Serranus cabrilla*), the Large-eye dentex (*Dentex macropthalmus*), the Common Pandora (*Pagellus erythrinus*) and miscellaneous species of Mullidae.

Such a heterogeneous distribution of seafood products is important knowledge from a Sustainable Supply Chain Management perspective since it indicates that the homogenous extraction of seafood products (species) is not possible across depths and that the provision of specifc products by supplying habitats varies with depth in the marine environment.

Extraction patterns by habitat

Whilst the relative fishing effort pertaining to depth, gear and season are important contextual information that help to characterise the Lipsi Small-Scale Capture Fishery. The effort by fishers to target specific habitats types (e.g. seagrass, rocky-algal habitat, coralline formations or sand) is *essential* information, since this directly informs the relative seafood product provision (abundance and richness of species) into the SSCF supply chain that can be directly linked to identified habitat types.

Of the 139 fishing trips, 74 (53.2 %) targeted *Posidonia oceanica* habitat and 41 (29.5 %) targeted Rocky-Algal habitat. 16 (11.5 %) targeted coralline habitat and only 8 (5.8 %) fished over bare sand habitat. (Figure 137).

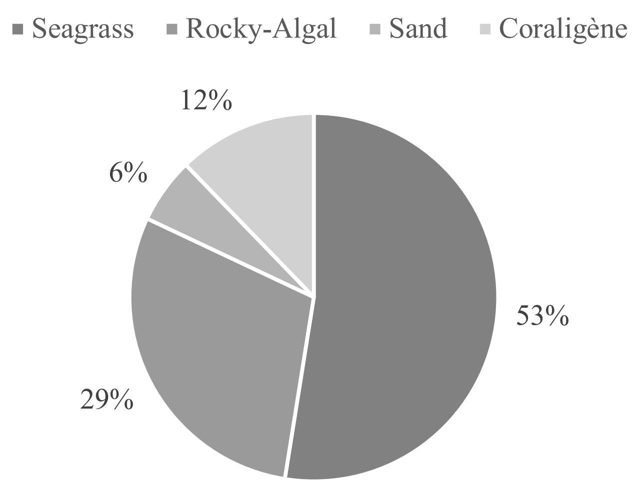


Figure 113. Relative fishing effort by habitat type. Over half of the fishing effort targeted seagrass meadows.

Of the 69 species recorded in landings, 62 species could be expected to show a degree of habitat association (benthic, epi-benthic and demersal species). Pelagic species excluded from this analysis include the sea needle (*Belone belone*) and species of Jacks (Carangidae) and Mackerels and Tunas (Scrombridae). A comparable total number of species (total species richness) was recorded from *Posidonia* (56) and Rocky-algal (47) habitats, while the Coralligène (25) had a value of around half of these and sand habitats (17) even fewer (Table 42).

Table 29. Number of species recorded in each of the four habitats including shared habitats and unique species.

	Habitat			
Type of species	**Seagrass**	**Rocky-algal**	**Coralligène**	**Sand**
(a)				
Unique species	7	5	0	0
Total species	56	47	25	17
Shared between two habitats	27	6	5	
Shared among four habitats	0			
Total number of species	62			

27 species were in common to both *Posidonia oceanica* seagrass meadows and rocky-algal habitats, and 5 species were in common to both Rocky-Algal and Coralligène habitats. *Posidonia oceanica* seagrass meadows and Coralligène reefs are separated by depth in the marine environment and share 6 species in common. Neither coralligène nor sandy-bottoms showed unique species diversity. The Mullidae and the Common Octopus (*Octopus vulgaris*) were shared evenly among all four habitats. No species were shared over all four habitats, but the Dusky spinefoot (*Siganus luridus*) was common between all shallow water habitats *Posidonia oceanica,* rocky-algal and sand habitats.

Fishers deployed Gill (35.1%) and Trammel (64.9%) nets when fishing in *Posidonia oceanica* seagrass meadows. Gill (7.3%) and Trammel (90.2%) when fishing in Rocky-Algal habitats. Trammel (16.7%) and Longline (83.3%) when fishing in Coralligène habitat, and Gill nets (100%) when fishing over sand. Fishers also used Handlines for targeting squid (*Loligo vulgaris*) in the water column. This was not linked explicitly to benthic habitat types. Fishery landings data revealed mean species richness of landed fish to be highest from seagrass 8.51 (±0.54). This was followed by rocky-algal 7.22 (±0.47) and coralline 7.00 (±0.32). Sand exhibited the lowest species richness 5.13 (±0.53) (Figure 138).

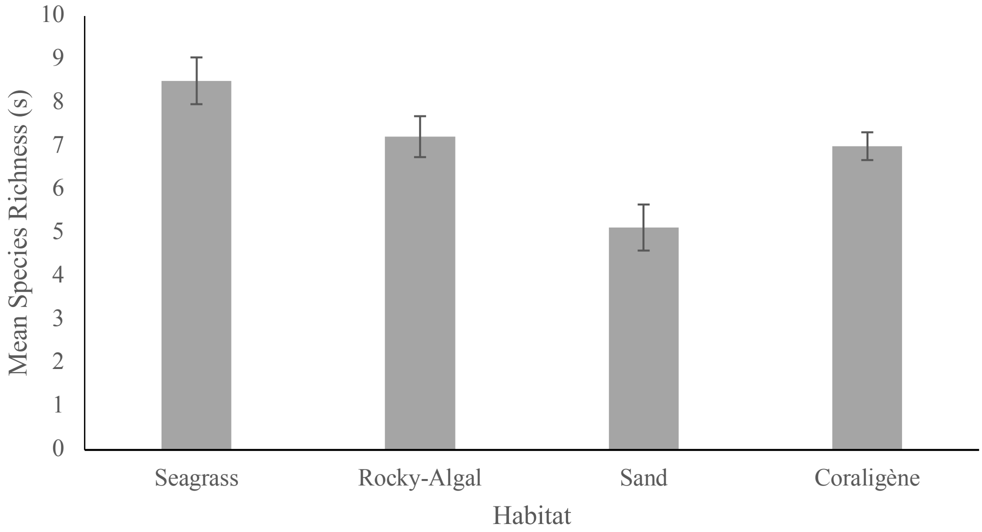


Figure 114. Mean (±SE) species richness per fishing trip from the targeting each type of habitat (across seasons and gears)

Fishery landings data revealed mean species abundance of landed fish to be highest from Coralline 69.47 (±5.63). This was followed by Seagrass 41.88 (±5.07) and Rocky-Algal 33.54 (±4.59). Sand exhibited the lowest species abundance 17.00 (±2.59) (Figure 139).

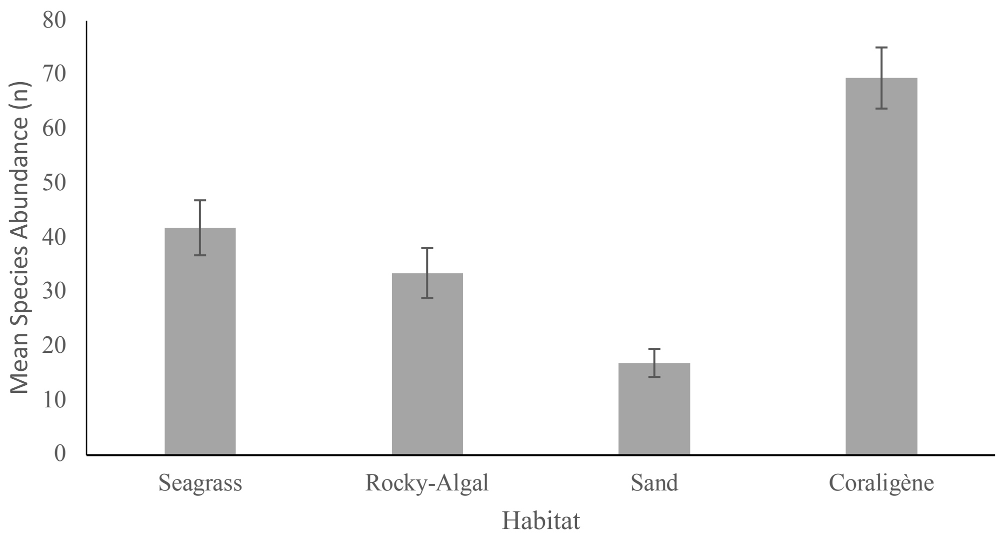


Figure 115. Mean (±SE) species abundance per fishing trip from targeting each type of habitat (across seasons and gears)

ANOSIM confirmed that the assemblages of species recorded in landings differed significantly between habitats (Global R = 0.458, $p = 0.01$). Although significant, the magnitude of difference between seagrass and rocky-algal habitats was small (Global R 0.079, $p = 0.019$). However, the differences between these two habitats and between all other habitats was marked (R = > 0.642, p => 0.01).

Superimposed Bray-Curtis clusters onto the MDS ordination (Figure 140) showed this differentiation between habitats. Although there was some separation between Seagrass and Rocky-Algal habitats, it is the clustering of Sand and Coralline that shows the most dissimilarity from both each other, and the Seagrass/Rocky-Algal habitat types. The low similarity levels of the clusters (10%) illustrated that differences between gear types were present at low resolutions.

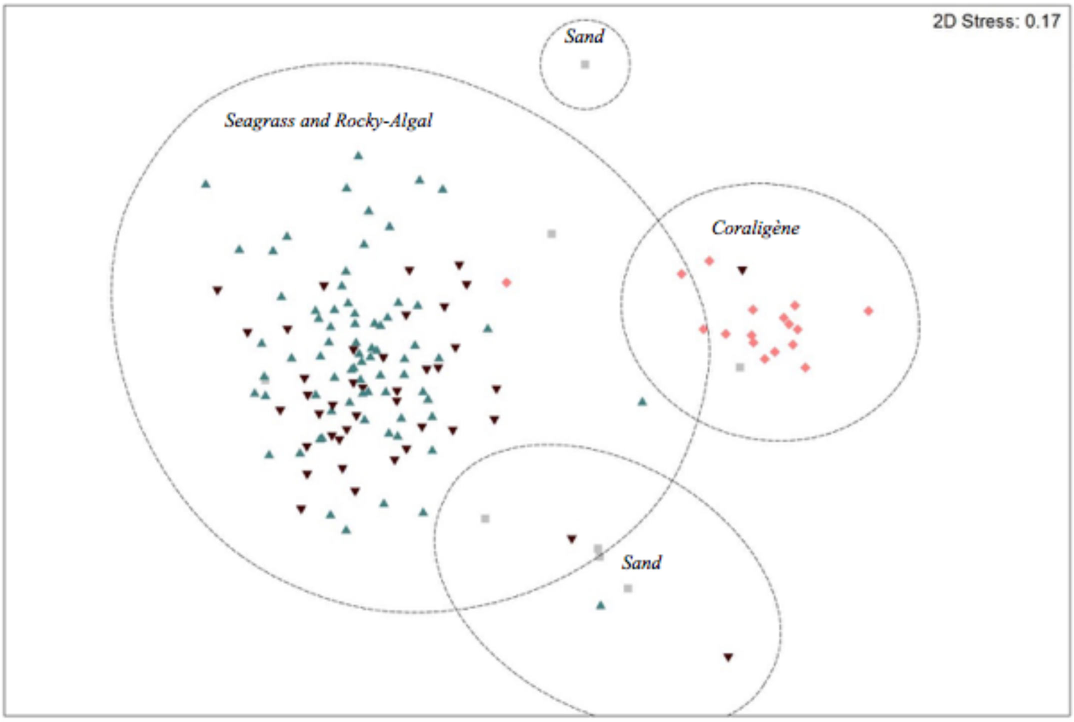


Figure 116. NMDS configuration with superimposed Bray-Curtis similarity clusters at the 10% level for sample comparison of fish species abundance, by gear: Seagrass (▲), Rocky-Algal (▼), Sand (■) and Coralline ( )).

SIMPER analysis revealed average similarity of 37.67 in the Spring, 38.10 in the summer and 16.74 in the Autumn. This data highlighting the similarity in species assemblage from landings conducted Spring and Summer seasons, in comparison to the more diverse fishery of Autumn. Group similarities are presented for the highest contributing species with a cut-off percentage of 75.0% (Table 43).

Table 30. Highest assemblage similarities for each habitat (across gear, season and depth) and the relative contributions of the highest contributing species. *D.macroptalmus* = *Dentex macroptalmus*

Species	Mean Abundance	Mean Similarity	±StDev Similarity	Contribution %	Cumulative %
Seagrass					
Average similarity: 36.51					
Siganus luridus	4.64	12.97	1.28	34.69	34.69
Sparisoma cretense	3.27	7.76	1.01	21.27	55.96
Oblada melanura	3.05	5.80	0.68	15.89	71.85
Scorpaena scrofa	1.31	2.23	0.65	6.12	77.97
Rocky-Algal					
Average similarity: 34.19					
Siganus luridus	5.03	14.64	1.04	42.82	42.82
Sparisoma cretense	3.53	9.86	1.23	28.85	71.66
Scorpaena scrofa	1.78	2.76	0.58	8.08	79.75
Sand					
Average similarity: 12.61					
Loligo vulgaris	3.26	7.71	0.64	61.12	61.12
Sphyraenidae sp.	2.05	1.75	0.19	13.89	75.01
Coralline					
Average similarity: 54.25					
Serranus cabrilla	5.41	20.70	2.23	38.16	38.16
D. macrophthalmus	4.91	15.07	1.07	27.77	65.92
Pagellus erythrinus	3.55	11.93	1.66	21.99	87.91

Taken together the results from season, gear, depth and habitat reveal that the Lipsi Small-Scale Capture Fishery is a multi-gear, multi-species fishery that adapts both its type of fishing gear, and the depth of deployment of its gear seasonally. This is a potential risk factor to the Lipsi SSCF supply chain since product supply is seasonally variable and inconsistent in both volume (abundance) and type (richness).

Also, and critical to the Small-Scale Capture Fishery conceptual framework, the data reveals that fishers target specific habitats to capture species that associate with those habitats; most notably the Saddled seabream (*Oblada melanura*) the Mediterranean parrotfish (*Sparisoma* cretense), the Large-scaled scorpionfish *(Scorpaena* scrofa) and the Dusky spinefoot (*Siganus luridus*) which associated to the shallow water (<50m) *Posidonia oceanica* seagrass meadows and rocky-algal reefs, and are species central to the supply chain provisioning of the SSCF (see 8.4.2). Of note the Large-eye dentex (*Dentex macrophthalmus),* Comber (*Serranus cabrilla*) and Common Pandora (*Pagellus erythrinus*) are those species that provision the SSCF from the targeting of the deeper water Coralline habitat (50m-100m).

Extraction patterns by location

Wind direction (16-Points Compass), wind speed (Australian Institute of Marine Science categories) and cloud cover (measured in Oktas) were recorded throughout the survey period (Table 44).

Table 31. Recorded wind direction, AIMS category (as a proxy for speed) and cloud cover were recorded with landings data from March until November.

Season	Spring			Summer			Autumn		
Month	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
Dominant Wind Direction (16-Point Compass)	SW	W	NW	NW	NW	NW	NW	NW	W
Mean Wind Category (AIMS categories)	1	2	2	2	2	2	2	2	1
Mean Cloud Cover (Oktas)	5	3	3	1	0	0	1	1	2

From around the middle of May until the Middle of October the wind was generally consistent from the north-west; in line with expectations of the seasonal “Meltemi” (Table 44, Figure 141). Cloud cover also decreased over the summer months.

These stable weather patterns made fishing activity predictable over this period, with fishers predominantly choosing to fish along the sheltered leeward side of the island; along the southern coastline and offshore islets. Conversely, wind speed, direction and cloud cover were inconsistent in early Spring and late Autumn, again in line with season expectations, which made fishing activity out of the southern facing port a more opportunistic activity.

Figure 142 presents this fishing pressure as a 'heat map'. Larger numbers of clustered points result in darker red, highlighting areas of higher fish pressure.

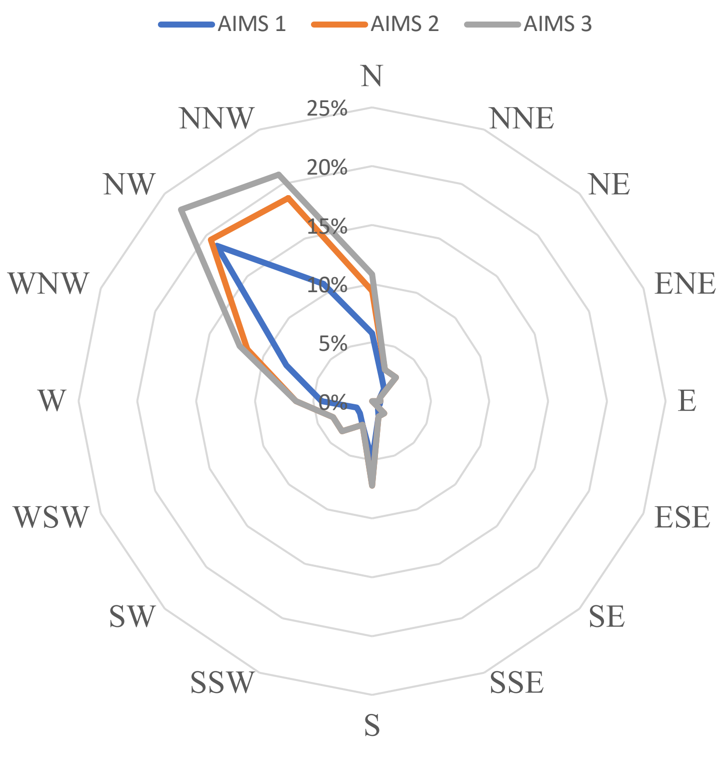


Figure 117. A 'Wind Rose' showing relative percentage of winds originating from each of the sixteen points of the compass. The vast majority of winds originating from the NW and NNW in line with the prevailing "Meltemi".

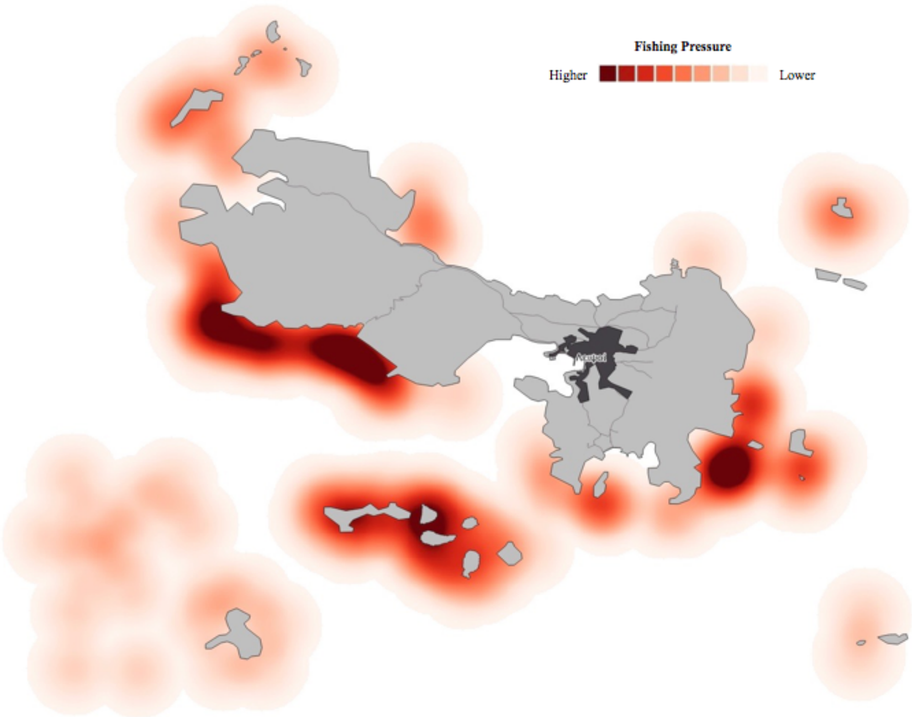


Figure 118. A heat-map of fishing pressure around Lipsi based on one-hundred and thirty-nine fishing trips

7.5.2. Fisheries Landings Data

General description of extraction patterns

In contrast to the Reported Fishery Data (RFD), the Fishery Landings Data (FLD) offers quantification of fishing effort and an indication of stock maturity through documentation of both the abundance and richness of species caught, and their relative size in relation to their length at maturity (Lm). Over a nine-month period from March 2014 until November 2014, 139 FLD surveys (Spring; n=41, Summer; n=59 and Autumn; n=39) were conducted with five fishers (3 regular, 2 occasional) from the Lipsi Fisherman's Association. 69 species of fish, cephalopod and decapod crustaceans were recorded as present in fishers catch (Table 45).

Table 32. Families and species recorded from quantitative fisheries landings data (n=139). The Top 10 most abundant species landed are highlighted in grey. The Top 10 most frequent are designated by *.

FAMILY	SPECIES	ANNUAL ABUNDANCE (%)	ANNUAL FREQUENCY (%)
Belonidae	*Belone belone*	0.3	7.2
Bothidae	*Arnoglossus laterna*	0.0	0.7
	Arnoglossus thori	0.0	1.4
Bothidae	*Bothus podas*	0.0	1.4
Carangidae	*Pseudocaranx Dentex*	0.1	2.2
	Seriola dumerelli	0.1	2.9
	Trachurus mediterraneus	0.1	2.2
Congridae	*Conger conger*	0.1	4.3
	Gnathophis mystax	0.0	0.7
Holocentridae	*Sargocentron rubrum*	0.1	3.6
Labridae	*Coris julis*	0.0	1.4
	Labrus bergylta	0.0	0.7
	Labrus mixtus	0.0	0.7
	Labrus viridis	0.1	2.9
	Symphodus roissali	0.0	0.7
	Symphodus rostratus	0.0	0.7
	Symphodus tinca	0.8	25.2*
	Thalassoma pavo	0.0	0.7
Mugilidae	*Mugilidae sp.*	0.0	2.2
Mullidae	*Mullidae sp.*	0.7	12.9
Muraenidae	*Muraena helena*	0.4	12.2
Phycidae	*Forkbeard*	0.5	12.9
Pomacentridae	*Chromis chromis*	0.1	2.9
Rajidae	*Rajidae sp.*	0.2	5.8
Scaridae	*Sparisoma cretense*	11.3	68.3*
Scianidae	*Umbrina cirrosa*	0.0	0.7
	Sciaena umbra	0.1	3.6
Scyliorhinidae	*Scyliorhinus canicula*	0.4	6.5
Scombridae	*Auxis rochei*	0.2	3.6
	Euthynnus alleteratus	0.2	4.3
	Sarda sarda	0.1	4.3
	Scomber japonicus	0.8	14.4
Scorpaenidae	*Scorpaena notata*	0.1	5.8
	Scorpaena porcus	2.1	38.1*
	Scorpaena scrofa	2.9	47.5*

	Scorpaena elongata	0.0	0.7
Serranidae	*Serranus cabrilla*	9.9	16.5*
	Serranus scriba	0.3	11.5
Siganidae	*Siganus luridus*	30.5	71.9*
	Siganus rivulatus	0.2	6.5
Sparidae	*Spicara maena*	0.3	7.9
	Spicara smaris	0.0	1.4
	Boops boops	0.4	10.1
	Dentex dentex	0.3	10.8
	Dentex gibbosus	0.0	1.4
	Dentex macrophtalmus	12.0	10.1
	Diplodus annularis	1.0	20.1
	Diplodus sargus sargus	0.3	10.1
	Diplodus vulgaris	1.0	30.2*
	Oblada melanura	14.1	43.2*
	Pagrus pagrus	0.3	2.6
	Pagellus acarne	0.5	2.9
	Pagellus bogaraveo	3.0	15.1
	Pagellus erythrinus	0.4	2.7
	Sarpa salpa	0.3	10.8
	Sparus aurata	0.1	4.3
	Spondyliosoma cantharus	0.4	10.1
Sphyraenidae	*Sphyraenidae sp.*	0.1	0.7
Squalidae	*Squalus acanthias*	0.0	1.4
Synodontidae	*Synodus saurus*	0.0	1.4
Trachinidae	*Trachinus radiatus*	0.0	0.7
Triglidae	*Triglidae sp.*	0.1	3.6
Uranoscopidae	*Uranoscopus scaber*	0.6	19.4*
Zeidae	*Zeus faber*	0.1	2.2
Octopodidae	*Octopus vulgaris*	0.5	15.8
Sepiidae	*Sepia officinalis*	4.1	34.5*
Loliginidae	*Loligo vulgaris*	1.2	15.1
Scyllaridae	*Scyllarides latus*	0.3	10.8
Palinuridae	*Palinurus elephas*	0.2	4.3

A total of 5749 fish (from 64 species, 26 families), 341 cephalopod molluscs (from 3 species, 3 families) and 27 decapod crustaceans (from 2 species, 2 families) were recorded. The top ten most abundant species constituted 85.2% of the overall landed catch. The top thirty species landed accounted for 96.7%. Over half of the species landed (n=38) were only done so very rarely; each making up less than 0.2% of the total landed catch.

The most abundant and frequently sampled fish was the Dusky Spinefoot (*Siganus luridus*) which was recorded (1 or more individuals) in 71.9% of the seasonal sampled catch (Figure 143). The species constituted 30.5% of the overall abundance (number of individual fish), and averaged around 38% (±24.0) % of the total number of individuals in each sample where it was recorded. This species is established in the wider region and has been responsible for an 'extraordinary' transformation in coastal rocky-algal habitat structure from well-developed native algal assemblages to 'barrens' with a dramatic decline in habitat complexity, biodiversity and biomass (Sala et al., 2011; Galil et al, 2015). The presence of this invasive species in Lipsi's waters can be expected to have an impact on the quality of rocky-algal habit and thus the nature of the habitats product provisioning into the Lipsi SSCF supply chain.

Figure 119. The invasive rabbitfish (*Siganus luridus*) dominated the catch of the small-scale fishery; landed in over 70% of the sampled landings and accounting for just under 40% of individuals in each sample.

The second most abundant species was the Saddled Seabream (*Oblada melanura*) which was found in 43.2 % of samples. The species constituted 14.1% of the overall catch abundance for the year and made up around 25.0 (±25.0) % of each sample where it was recorded (Figure 144). This species is native to the region and forms aggregations over rocky-bottoms and seagrass meadows, it has a 'Very High' commercial value (FishBase, 2016).

Figure 120. The saddled seabream (*Oblada melanura*) was the second most landed species, peaking in abundance in through May and June (On 10-05-2014 ninety three saddled seabream were caught in a gill net by a single fisher).

The third most abundant species was the Large-eye dentex (*Dentex marcophthalmus*) found in just 10.1% of sampled landings (Figure 145). The species constituted 12.0% of the overall catch abundance for the year but accounted for 46.0 (±15.0) % of the landings when present highlighting that the species most likely forms aggregations over the coralline habitat where it was fished.

Figure 121. The Large-eye dentex (*Dentex macrophthalmus*) was the third most landed species by the Lipsi Small-Scale Capture Fishery (Photo FishBase 2016).

Other species that were frequently recorded were the Mediterranean Parrotfish (*Sparisoma cretense*) that were recorded in 68.3 % of landed catch and formed 11.3% of the seasonal abundance, the Common cuttlefish (*Sepia officinalis*) in 35 % of sampled catch, but formed just 4.1% of seasonal abundance and the Red (*Scorpaena scrofa*) and Black scorpionfishes (*Scorpaena porcus*) at 47.5 % and 38.1 % of sampled catches, and accounted for 2.9% and 2.1% of the overall abundance of fish landed respectively (Figure 146).

Figure 122. A Largescale scorpionfish (*Scorpaena scrofa*) being measured during landings. Just 3.8% of this species was below the length at maturity when landed, despite its status as a regionally overfished species (Tsikliras et al., 2013).

The Common two-banded seabream (*Diplodus vulgaris*), the Annular seabream (*Diplodus annularis*), the East Atlantic peacock wrasse and the Stargazer (*Uranoscopus scaber*) each occurred frequently; in around one-fifth (or higher) of sampled catches but in relatively small numbers. In contrast, species such as the Comber (*Serranus cabrilla*) or Common Pandora (*Pagellus erythrinus*) occurred in relatively high numbers but not frequently, suggesting they occur in small groups when they are found.

Species conspicuous by their low abundance are the IUCN endangered, Common seabream (*Pagrus pagrus*) and the Gilthead seabream (*Sparus aurata*) and the Common dentex (*Dentex dentex)*. (Pennington et al, 2013, Tsikliras et al, 2013). The top five most abundant species recorded per fishing trip are presented for each season in Table 46.

Table 33. Top five most abundant species recorded in the catch by season.

SPRING (Mar-Apr-May)		SUMMER (Jun-Jul-Aug)		AUTUMN (Sep-Oct-Nov)	
Siganus luridus	12.3 (±14.6)	*Siganus luridus*	18.1 (±26.9)	*D. macrophtalmus*	11.8 (±21.9)
Oblada melanura	11.4 (±23.0)	*Sparisoma cretense*	7.2 (±7.0)	*Serranus cabrilla*	10.5 (±15.7)
Sparisoma cretense	5.2 (±8.8)	*Oblada melanura*	5.1 (±19.1)	*Pagellus erythrinus*	4.2 (±5.9)
Sepia officinalis	4.0 (±8.5)	*Sepia officinalis*	1.3 (±2.0)	*Siganus luridus*	2.4 (±5.5)
Scorpaena scrofa	2.4 (±1.3)	*Scorpaena scrofa*	1.3 (±1.6)	*Loligo vulgaris*	1.3 (±5.5)

The Dusky Spinefoot (*Siganus luridus*) dominated the catch during both the Spring (12.3 ±14.6) and Summer (18.1 ±26.9) seasons. This species also made the top five in Autumn (2.4 ±5.5) despite a marked change in gear deployment and associated catch abundance. A temporal peak in abundance of the Saddled seabream (*Oblada melanura*) during May and June ensured that the species was prominent in both Spring (11.4 ±23.0) and Summer (5.1 ±19.1) landings. However, after this peak period in late Spring, the abundance of this species decreases dramatically with very few individuals landed in Autumn (0.3 ±1.0). The Mediterranean Parrotfish (*Sparisoma cretense*), the Common cuttlefish (*Sepia officinalis*) and the Red Scorpionfish (*Scorpaena scrofa*) were also regular species characterising both Spring and Summer landings which declined markedly in Autumn. The most abundant species were often common to more than one habitat type, especially in the shallow coastal zone (<50m).

The FLD data shows that different habitats (providers) supply different volumes of product into the SSCF supply chain (Table 47). Unlike in traditional business supply chains, where 'units' of product may be requested, and produced 'to order', fishers (and the fishing industry) face the challenge of variable supply, both in abundance (volume) and richness (variety) of product. This creates challenges for Sustainable Supply Chain Management (SSCM) but the FLD data can help to inform the SSCM using the SSCF conceptual framework. However, if it is understood that particular habitats have a greater role in provision particular species, and that particular habitats will provide products in predicable abundances, then those habitats (and their associated assemblages) can be targeted for better resource management.

It is this concept forms the backbone of current Ecosystem Based Fisheries Management (EBFM) whereby fisheries managers seek to ensure continuity of seafood product supply by protecting the habitats that provision the fishery and which forms the basis for the SSCF SSCM conceptual framework articulated in this thesis.

Table 34. Top five most abundant species landed by habitat type. The species landed from the un-vegetated sandy bottom habitat show low abundances and are not species that are habitat 'linked' i.e. species that show a species-habitat association with un-vegetated sandy bottoms.

HABITAT							
***P. oceanica* seagrass meadow (<50m)**		**Rocky-Algal habitat (<50m)**		**Coralline formations (>50m)**		**Un-vegetated sandy bottom All depths**	
Top five species	**Mean number landed per trip (±SD)**	**Top five species**	**Mean number landed per trip (±SD)**	**Top five species**	**Mean number landed per trip (±SD)**	**Top five species**	**Mean number landed per trip (±SD)**
S.luridus	13.2 (±16.7)	*S. luridus*	16.6 (±27.7)	*D. macrophtalmus*	27.6 (±24.9)	*S. officinalis*	4.5 (±12.3)
O. melanura	9.7 (±19.1)	*S. cretense*	5.1 (±5.6)	*S. cabrilla*	25.6 (±16.7)	*Sphyraenidae sp.*	2.1 (±5.3)
S. cretense	6.1 (±8.2)	*S. scrofa*	1.9 (±2.6)	*P. erythrinus*	9.4 (±7.0)	*S. cabrilla*	1.6 (±4.6)
S. officinalis	2.0 (±4.0)	*S. officinalis*	1.5 (±2.8)	*P. boaraveo*	1.9 (±4.8)	*L. vulgaris*	1.5 (±1.5)
S. scorfa	1.4 (±2.1)	*O.melanura*	1.4 (±4.1)	Mullidae sp.	1.3 (±4.3)	*D. macrophtalmus*	1.5 (±4.2)

Extraction patterns by Length

For successful Sustainable Supply Chain Management (SSCM), the maturity of the individual fish that are associated to a habitat are also an important factor, since juveniles should not be the target catch of a fishery. Indeed, for effective Ecosystem Based Fisheries Management (EBFM), an understanding of the following length related elements of landed catch is necessary;

a) **Stock Maturity** (how many individuals of a given species are greater than the Length at maturity for that species)
b) **Trophic Level** (how many individuals of a given species are being landed from a given trophic level)

These elements are important because; a) if species are not reaching maturity then they are not reproducing, and therefore not contributing individuals for future seafood supply, and b) it is often those species that occupy higher trophic levels within the fishery that are the species targeted for human consumption (Pauly et al., 1995). In addition, larger fish, are often also the most fecund – Big Old Fat Fecund Female Fish or BOFFFFs (see Hixon et al, 2014). Extraction of these can have negative ecosystem effects.

Table 48 shows the mean size, and size range, for fishery species, and some information on length at maturity for each species. The clear majority of fish sampled were under 30cm in length. Fish larger than this were adults (or intermediates) of species of pelagic fish such as Sea needles (Belonidae), Jacks (Carangidae), Mackerels and Tunas (Scombridae), or larger predators such as Conger eels (Congridae) and Moray eels (Muraenidae).

Table 35. A table showing the mean size of species landed, the size range of species landed, and the length at maturity as presented on fishbase.org. sealifebase.org. Grey highlights those species those species recorded with mean catch lengths lower than the species Lm.

FAMILY	SPECIES	Size Range (cm)	Mean Size (cm)	Length at Maturity (cm)
Belonidae	*Belone belone*	30.0 – 105.2	83.8 (±15.7)	45.0

Carangidae	*Pseudocaranx Dentex*	25.2 – 35.0	30.5 (±4.1)	28.0
	*Seriola dumerelli**	20.7 – 27.2	23.7 (±2.5)	109.0
	Trachurus mediterraneus	18.6 – 31.5	27.4 (±5.2)	20.0
Congridae	*Conger conger*	50.0 – 96.0	67.9 (±18.1)	67.0
Labridae	*Symphodus tinca*	8.0 – 30.6	21.9 (±4.3)	10.0
Mullidae	*Mullus surmuletus*	18.0 – 30.5	22.5 (±3.6)	16.1
Muraenidae	*Muraena helena*	55.0 – 98.0	84.6 (±12.3)	75.5
Phycidae	*Phycis phycis*	24.0 – 34.5	29.1 (±2.8)	22.0
Scaridae	*Sparisoma cretense*	13.0 – 38.0	23.0 (±2.8)	15.5
Scyliorhinidae	*Scyliorhinus canicula**	34.0 – 58.2	45.8 (±6.9)	57.0
Scombridae	*Auxis rochei*	31.2 – 59.0	42.5 (±9.1)	35.0
	Euthynnus alleteratus	30.1 – 67.0	42.7 (±9.5)	41.8
	Sarda sarda	24.2 – 68.0	46.3 (±17.3)	37.0
	Scomber japonicus	15.0 – 45.1	32.8 (±5.3)	26.1
Scorpaenidae	*Scorpaena porcus*	12.0 – 28.4	20.6 (±3.2)	14.4
	Scorpaena scrofa	10.0 – 35.5	22.9 (±4.2)	17.0
Serranidae	*Serranus cabrilla*	6.5 – 24.5	18.0 (±2.0)	17.5
	Serranus scriba	14.1 – 24.2	19.0 (±3.3)	17.3
Siganidae	*Siganus luridus*	7.0 – 34.2	18.7 (±1.8)	14.2
Sparidae	*Spicara maena*	13.2 – 20.1	17.2 (±1.8)	10.3
	Boops boops	13.2 – 26.3	18.6 (±4.2)	13.0
	Dentex dentex	21.7 – 77.0	43.8 (±18.0)	34.6
	Dentex macrophtalmus	13.0 – 24.5	17.4 (±1.8)	14.0
	Diplodus annularis	6.0 – 26.0	14.8 (±6.0)	11.2
	Diplodus sargus	17.5 – 29.5	23.6 (±4.6)	25.0
	Diplodus vulgaris	10.0 – 24.4	18.1 (±3.0)	17.0
	Oblada melanura	15.0 – 37.3	26.1 (±2.2)	12.0
	Pagrus pagrus	14.6 – 25.0	20.7 (±3.2)	26.6
	Pagellus acarne	16.4 – 35.5	22.0 (±7.9)	16.0
	Pagellus bogaraveo	14.3 – 15.7	23.3 (±4.0)	25.0
	Pagellus erythrinus	13.0 – 33.4	15.2 (±0.5)	14.7
	Sparus aurata	24.3 – 29.8	27.0 (±2.2)	33.0
	Spondyliosoma cantharus	17.6 – 34.5	21.4 (±4.7)	19.7
Sphyraenidae	*Sphyraenidae sp.*	21.0 – 83.0	58.2 (±10.3)	55.0

Uranoscopidae	*Uranoscopus scaber*	7.0 – 32.5	25.3 (±4.8)	14.0
Sepiidae	*Sepia officinalis*	6.0 – 22.8	13.6 (±2.8)	16.0
Loliginidae	*Loligo vulgaris*	8.0 – 25.2	18.6 (±4.0)	14.0
Scyllaridae	*Scyllarides latus*	14.0 – 30.0	21.1 (±6.8)	15.0
Palinuridae	*Palinurus elephas*	22.0 – 33.0	26.8 (±4.5)	16.0

Seven commonly consumed seafood species (see Chapter 9) were landed with a mean size lower than the Length at maturity (Lm) of the species (highlighted in grey), this means that many individuals from these species would not yet have had the chance to reproduce, thus risking the future seafood supply of the species. Yet, overall, seventeen habitat-associated species were landed with greater than 25% of individuals below the length of maturity for the species. Every one of these seventeen species (100%) were species with a Trophic Level >3.0, and therefore are predators, and six, (35.3%), were species with a Trophic Level > 4.0. The extraction of these species represents the extraction of the very highest predators in the food web.

Amongst the seventeen, are eight species that were identified by Tsikliras (2013) as being regionally 'Overfished' and therefore of immediate supply chain sustainability concern. These are the Common dentex (*Dentex dentex*), the Painted comber (*Serranus scriba),* the Gilthead seabream (*Sparus aurata*), the Annular seabream (*Diplodus annularis*) the Comber (*Serranus cabrilla),* the White seabream (*Diplodus sargus*), the Black seabream (*Spondyliosoma cantharus*). Notably each of these are all valued food fish. However, Tsikliras et al (2013) presented the Scopaenidae as overfished, but in this study, just 3.8% (*Scopanea* scrofa) and 2.0% (*Scorpaena porcus*) of landed catch from these species of this family were below the length at maturity. He also presented *Oblada melanura* and Mullidae sp. as overfished, yet no individuals were landed below the length of maturity for either of these species (Table 49).

A point of concern raised from this study is the absence of the Atlantic mackerel (*Scomber scombrus*) which is presented by Tsikliras et al (2013) as overfished, but was not present in landings on Lipsi at all (one fisher reported the last landing of this species, locally known as "Skubri" over a decade ago). Also of note in this study, are the popular targets for spearfishers; the Dusky grouper (*Epinephelus marginatus*) and the White grouper (*Epinephelus aeneus*), which were both declared ‘overfished’ by Tsikliras etl al (2013). However, these species are not landed by the small-scale fishery, and are instead a target of recreational spearfishers.

Six pelagic species that were landed with greater than 25% of individuals below the length of maturity for the species. These species were exclusively large pelagic predators, (Jacks and Tunas) which would likely have been foraging in the coastal zone at the time of their extraction by the Lipsi SSCF (Table 50).

Table 36. Percentage of habitat-associated species landed in this study, as ranked by Trophic Level (FishBase, 2016). Status of stock from Tsikliras et al, 2013.

Family	Species	Trophic level (±SE)	% < Lm	Status of stock
Zeidae	*Zeus faber*	4.5 (±0.8)	25.0	Fully exploited
Sparidae	*Dentex dentex*	4.5 (±0.4)	35.0	Overfished
Scorpaenidae	*Scorpaena scrofa*	4.3 (±0.5)	3.8	Overfished
Congridae	*Conger conger*	4.3 (±0.4)	50.0	Fully exploited
Phycidae	*Phycis phycis*	4.3 (±0.3)	0.0	No data
Muraenidae	*Muraena helena*	4.2 (±0.6)	29.0	No data
Sparidae	*Pagellus bogaraveo*	4.2 (±0.6)	100.0	No data
Sparidae	*Dentex gibbosus*	4.1 (±0.6)	100.0	No data
Sparidae	*Pagrus pagrus*	3.9 (±0.2)	100.0	Fully exploited
Scorpaenidae	*Scorpaena porcus*	3.9 (±0.2)	2.0	Overfished
Labridae	*Labrus viridus*	3.9 (±0.4)	0.0	No data
Scyliorhinidae	*Scyliorhinus canicula*	3.8 (±0.3)	94.1	No data
Sparidae	*Pagellus acarne*	3.8 (±0.0)	0.0	No data
Sciaenidae	*Sciaena umbra*	3.8 (±0.5)	40.0	No data
Serranidae	*Serranus scriba*	3.8 (±0.3)	53.0	Overfished
Sparidae	*Sparus aurata*	3.7 (±0.0)	100.0	Overfished
Sepiidae	*Sepia officinalis*	3.6 (±0.5)	81.3	Fully exploited
Sparidae	*Diplodus annularis*	3.6 (±0.0)	38.5	Overfished
Holocentridae	*Sargocentron rubrum*	3.6 (±0.3)	0.0	No data
Sparidae	*Dentex macrophtalmus*	3.5 (±0.4)	1.4	Fully exploited
Sparidae	*Diplodus vulgaris*	3.5 (±0.1)	40.0	No data
Mullidae	*Muillidae sp.*	3.5 (±0.3)	0.0	Overfished
Sparidae	*Pagellus erythrinus*	3.5 (±0.1)	12.5	Overfished

Serranidae	*Serranus cabrilla*	3.4 (±0.3)	36.2	Overfished
Sparidae	*Diplodus sargus*	3.4 (±0.1)	45.5	Overfished
Sparidae	*Oblada melanura*	3.4 (±0.4)	0.0	Overfished
Sparidae	*Spondyliosoma cantharus*	3.3 (±0.2)	36.4	Overfished
Labridae	*Symphodus tinca*	3.3 (±0.3)	4.3	No data
Labridae	*Labrus bergylta*	3.2 (±0.0)	0.0	No data
Scaridae	*Sparisoma cretense*	2.9 (±0.3)	1.1	No data
Sparidae	*Sarpa salpa*	2.0 (±0.0)	23.5	Overfished
Siganidae	*Siganus luridus*	2.0 (±0.0)	0.5	No data
Siganidae	*Siganus rivulatus*	2.0 (±0.0)	0.0	No data

Table 37. Percentage of pelagic species landed in this study, as ranked by Trophic Level (Fishbase.org). Status of stock from Tsikliras et al, 2013.

Family	**Species**	**Trophic level (±SE)**	**% < Lm**	**Status of stock**
Carangidae	*Seriola dumerelli*	4.5 ±(0.0)	100.0	Fully exploited
Scombridae	*Euthynnus alleteratus*	4.5 (±0.0)	54.0	No data
Scombridae	*Sarda sarda*	4.5 (±0.0)	33.3	Overfished
Scombridae	*Auxis rochei*	4.3 (±0.7)	30.0	No data
Belonidae	*Belone belone*	4.2 (±0.4)	5.9	Overfished
Carangidae	*Pseudocaranx dentex*	3.9 (±0.6)	50.0	No data
Carangidae	*Trachurus mediterraneus*	3.8 (±0.3)	20.0	No data
Scombridae	*Scomber japonicus*	3.4 (±0.01)	10.3	Overfished

7.5.3. Semi-Structured Interview – Fishers Knowledge

In August 2015, 7 of the full-time fishers were interviewed using a semi structured interview. All interviewed fishers were male, and aged between 40-69 years of age. Additionally, all fishers had been fishing for over 10 years (Range: 10-49 years) with all fishers reporting fishing as their only source of income.

Temporal Changes in Small-Scale Capture Fishery Seafood Supply

Temporal changes in SSCF seafood supply were elicited in Semi-Structured Interview questions 3, 4 and 5:

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3. How would you describe the current conditions of fish stocks regarding abundance?
a) Over the last 5 years
( ) unaltered ( ) declined ( ) increased
b) Over the last 15 years
( ) unaltered ( ) declined ( ) increased

4. Are there any overexploited fish species in this region? ( ) Yes ( ) No If Yes, which species?

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5. Are there any species that you discarded in the past (not good enough to eat or sell) that today are eaten/sold ( )Yes( )No
If Yes, which species?

Why is this species now kept?

When asked to describe the islands current condition of fish stocks regarding abundance all fishers answered unanimously that there had been a decline both in the last 5 years (100%), and over the last 15 years (100%). One of the older fishermen remarked that;

"the abundance of fish had been declining since 1990…"

and another that;

"the fishing has got considerably worse, there are no fish left…".

The fishermen were then asked if there were any overexploited fish species in the region, once again all the fishermen answered unanimously that there were, in their opinion, overexploited species, commenting that;

"There are no fish left, so we catch whatever we can".

One fisher stated that;

"Nearly all the species of fish are overexploited, some have disappeared completely".

Fishers specified notable declines in the fish families Mullidae, Scaridae, Scorpaenidae and Sparidae. Fishers remarked on declines of the Dusky grouper (*Epinephelus marginatus*), Golden grouper (*Epinephelus costae*), Largescale scorpionfish (*Scorpaena scrofa*), Gilthead seabream (*Sparus* aurata), Mediterranean parrotfish (*Sparisoma cretense*) and the Common octopus (*Octopus vulgaris*) which were all mentioned as declining / disappearing from the shallow coastal waters (<50m). In deeper water (>50m) the trends were the same with the near disappearance of the fish species Red porgy (*Pagrus pagrus*) and John Dory (*Zeus faber*), the Surmulet (*Mullus surmulletus*), the Mediterranean slipper lobster (*Scyllarides latus*) and the European squid (*Loligo vulgaris*).

The fishermen were then asked if there are any species that they discarded in the past (not good enough to eat or sell) that today are eaten/sold. The most common answer was that there were none of the fish left that they considered either "good" or "bad", in fact there were hardly any fish of any type left to sell or eat! One fisherman remarked that Bogue (*Boops boops*), Comber (*Serranus cabrilla*) and Saddled seabream (*Oblada melanura)* are fish that traditionally would have not been eaten or sold, but are now consumed on the island. Another noted the increase in consumption in the home of the invasive rabbitfish; Dusky spinefoot (*Siganus luridus*).

Spatial Changes in Small-Scale Capture Fishery Seafood Supply

Temporal changes in SSCF seafood supply were elicited in Semi-Structured Interview questions 6.

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6. Is there a place in this region that was considered a good fishing site in the past due to the abundance and productivity of fish, but nowadays is considered overexploited? ( ) Yes ( ) No
When did that change?

Fishers were asked if there were locations around the island that were considered good fishing sites in the past due to the abundance and productivity of fish but nowadays considered overexploited. All the fishers answered saying that they consider the entire island overexploited;

"All of the island used to be good for fishing… [not anymore]. This started changing in the early 1990s [because] there are more ways of fishing than there used to be…"

"All of the island has been overexploited due to fishermen with large trawlers from other islands"

"There are many nets and fishing boats from other islands [coming to Lipsi] so fish are declining"

However, one fisher particularly noted a loss in productivity around Aspronisi and Makronisi (popular *Posidonia oceanica* seagrass and Rocky-Algal reef fishing grounds) and another a marked decline in the seas between Lipsi and Patmos (Coralline formations);

"The trawlers have destroyed this area [the Coralline]… now there are just shells left"

One of the eldest fishers (60-69, 45years fishing) described a series of regime shifts (sensu Rocha et al., 2015; Levin et al., 2015) occurring in this deep-water channel [the coralline formations] between Lipsi and Patmos. Here he described how species such as Red porgy (*Pagrus pagrus*) could be caught before "disappearing" in the late 1980s / early 1990s and being replaced by an abundance of Surmullet (*Mullus surmulletus*). Now he said that the Surmullet (*Mullus surmulletus*) have also 'disappeared' to be replaced by small species of shellfish.

Assessing fishing and marine biodiversity changes using fishers' perceptions in this manner is note without precedent, a similar study has also been conducted in the Western Mediterranean and Gulf of Cadiz by Marta Coll et al. (2014). In this study fishers (70%) cited specific fishing grounds where depletion occurred. Their interviews with fishers documented ecological changes of marine biodiversity during the last half of the century: 94% reported the decline of commercially important fish and invertebrates and 61% listed species that could have been extirpated, with frequent mentions to cartilaginous fish (Coll et al., 2014). Critically, their perceived declines and extirpations (local extinctions) were in line with available quantitative evaluations from stock assessments and international conventions, and were likely linked to fishing impacts.

Importantly, the Lipsi fishers experiences presented here reflect the long-term (1950-2001) trends in Hellenic waters (Moutopoulos et al., 2015), and, in particular, since 1995, where rapidly declining trends in landings that have been recorded (Tsikliras, 2013). What this suggests that intense fishing (overfishing) has removed to many individuals from the supply chain, preventing reproduction, and leading to stock declines and in some cases collapses (Tsikliras, 2013). Figure 147 shows a map of Lipsi island, whilst fishers were unanimous in the decline in fish supply over the whole area, specific reference was made to the shallow fishing grounds of

Aspronissi (top right) and Makronissi (bottom), and to the deeper water (50m-100m) coralline formations in the channel towards the south-west.

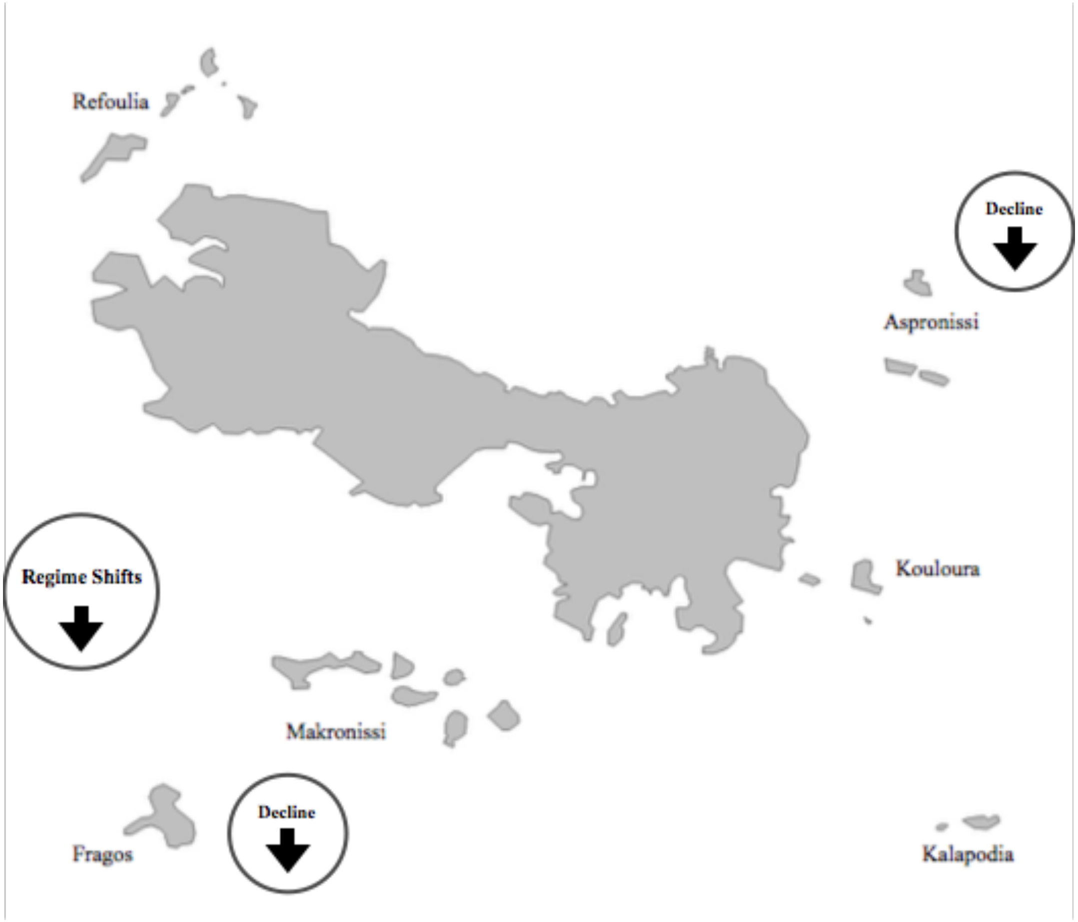

Figure 123. **Lipsi and its surrounding islets. Fishers stated that fishing has declined across the whole area but Aspronissi (top-right) and Makronissi (bottom-middle) were mentioned specifically. To the left of Makronissi and to the north of Fragos lies the deepwater channel of coraligéne formations separating Lipsi from Patmos.**

Fishers Suggested Small-Scale Capture Fishery Management Measures

Management measures suggested by fishers for management of the SSCF seafood supply were elicited in Semi-Structured Interview questions 7 and 8:

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7. Which area should be protected from fishing (if any)? Why?
8. What (management) measures do you think are important to improve the

catch/landings (and therefore income) in this region?

Opinions on potential supply chain management measures were elicited in questions 7 and 8. Fishers were asked if any areas around the island should be protected from fishing. The majority (n=6) favoured protection measures that covered the whole of the Lipsi seascape including one fisher specifically suggested the banning of trawlers from the local waters;

"The entire island should be protected from trawlers"

On the same topic another fisher articulated the need to protect spawning areas during spawning periods, and suggested a scheme for shifting areas of protection every few years to allow stocks to recover;

"Spawning areas should always be protected… Change the other protected areas every couple of years…"

The consensus across all seven fishers was that some element of protection for both habitat and fish (assemblage) was required if the decline in fish stocks was to be halted or reversed with fishers citing damage to the deeper coralline formations as a particular problem locally.

Fishers were asked what management measures they think would be important to improve the catch/landings in this region. All fishermen (n=7) referred to fishing gear adjustments; notably the increase of nets mesh size and hook size to decrease juvenile landings;

***"Larger net holes and smaller hooks"* [so we don't catch juveniles]**

Two fishers suggested the cessation of trawling activity in the region (since they perceived it damaged the seabed habitats) and another suggested the possibility for close-seasons where money was provided for them to live off during this time. Clamping down on un-licensed fishing and 'illegal activity' was linked to this;

"There is a lot of illegal activity… Trawlers should be stopped"

Overall there was a noticeable animosity towards the large-scale fishing fleet, who Lipsi SSCF fishers perceived to be taking 'all the fish' and 'destroying the fishing grounds' despite not being from the island. They are fishing Lipsi's waters, but living elsewhere.

7.5.4 Synergies and Triangulation

Interrogation of both the abundance and richness of species within the Lipsi seascape has highlighted a very complex spatial (location/depth), temporal (season) and behavioural (targeted habitats / gear choice) relationship regarding the extraction of fishery species from the marine environment for provisioning of the seafood supply chain. The site mapping of fishing pressure from Reported Fisheries Data (Figure 142) broadly correlates with the locations of decline in fisheries productivity referenced by fishers in the Fishers Ecological Knowledge semi-structured interview (Figure 147).

Principally it highlights the role that the prevailing "Meltemi" wind plays in influencing the small-scale capture fleets fishing behaviour on the island (Figure 141), with fishers in general choosing to pursue fishing activity along southern, sheltered, side of the island. The decision by fishers to predominantly (92% of the time) deploy gear within the 1m-50m depth range might also be linked to this prevailing influence, since depth generally increases with distance away from the landmass then fishers seeking shelter would be encouraged into fishing at shallower depths, and thus target those shallow water suppliers – the *Posidonia oceanica* seagrass meadows (53% of occasions) and rocky-algal reefs (29% of occasions).

Three-Way ANOSIM confirmed that the assemblages of species recorded in landings differed significantly between depth, gears and habitats (Global R = 0.195, *p*= 0.016). It appears that a conscious shift in target species occurs towards the end of summer (linked to consumer demand; see Chapter 9). This change is expressed by both a decreased fishing effort; in targeting seagrass and rocky-algal habitats at depths of <50m, and an increased fishing effort; in targeting deeper waters (>50m). Specifically, an increased deployment of longlines which target coralline habitat during the Autumn months. The Summer to Autumn change is also characterised concurrently by the deliberate targeting of squid (*Loligo vulgaris*), via handline ('jigging'), over the same period.

Critical to supply-side management, this data highlights the stratification of the Lipsi fishery according to habitat (seagrass/rocky-algal vs coralline habitats) which is also stratified by depth in the marine environment (seagrass and rocky-algal occur between 1m-50m vs coralline between 51m-100m). Here ANOSIM revealed the greatest differences were seen between seagrass meadows and coralline habitats (R = 0.912, *p*= 0.01) and rocky-algal and coralline habitats (R = 0.809, *p* = 0.01). In shallow waters seagrass meadows and rocky-algal habitat showed the greatest catch assemblage similarity (R = 0.079, *p* = 0.019). Essentially a stratification occurs between those habitats that are present in the 1m-50m depth range, versus those that occupy depths greater than 50m.

Therefore, for Small-Scale Capture Fishery (SSCF) Sustainable Supply Chain Management (SSCM) initiatives, consideration needs to be paid to productive habitat protection (productive suppliers) both in shallow <50m deep waters, but also >50m deep waters so as to ensure the continuity of seafood product supply that are associated from each of these habitat types.

This habitat/depth delineation also suggests that broadly speaking there exist two species assemblages; one of which generally associates to the seagrass and rocky-algal habitats of the 1-50m depth range, and another, which broadly associates with coralline formations at depths greater than 50m, although there is a species crossover between 26-75m (i.e. R = 0.112, *p* =0.038). Critically, outreach to fishers' ecological knowledge correlates these species depth associations, for example the reported declines of Mediterranean parrotfish (*Sparisoma cretense*), Largescale scorpionfish (*Scorpaena scrofa*) and Gilthead seabream (*Sparus aurata*) from the shallow water (<50m) fishery, and reported declines of John Dory (*Zeus faber),* Red porgy (*Pagrus pagrus*) and the Surmullet (*Mullus surmulletus*) from deeper waters (>50m).

These broad patterns can be seen amongst the top fifteen species (most abundant over the survey period) which are presented in Table 51, alongside three highly valued fishery species that were specifically mentioned during outreach to Fishers Ecological Knowledge. Whilst some of these species will not be those that are deliberately targeted (e.g. *Siganus luridus*) it can be assumed that fishers will expect to catch certain species depending upon the habitat they target, and therefore choose the most suitable gear for extraction.

The decision by fishers to focus fishing efforts on seagrass and rocky-algal habitats in the summer months suggests that fishers were targeting these habitats with the 'expectation' of the shared top ten catch contributions of *Siganus luridus, Sparisoma* cretense, *Oblada melanua, Scorpaena scrofa, Scorpaena porcus, Sepia officinalis*, *Diplodus vulgaris, Symphodus* tinca, and *Diplodus annularis*, but in the 'hope' of catching *Sparus aurata* and *Dentex dentex*. Four of these top ten species are popular with tourists, with *Sparus aurata* and *Dentex dentex* both highly esteemed. (see Chapter 9).

For coralline, the 'expectation' would be for *Serranus cabrilla*, *Dentex macropthalmus*, *Pagellus erythrinus, Pagellus acarne, Pagellus bogaraveo* and *Scyliorhinus canicula*, but with 'hope' of catching *Pagrus pagrus.* Large *Pagellus erythrinus* are served to tourists alongside *Pagrus pagrus* which is highly esteemed. Fishers only targeted sand on 6% or occasions, with species caught over these habitats being principally associated the water column, namely the common squid (*Loligo vulgaris*) and chub mackerel (*Scomber japonicus*).

Table 38. Top 15 most abundant species by fisheries catch, their spatial and temporal distributions, their life history parameters and perception of stock status.

Species	Total	Location Data		Abundance Data			Length Data			FEK	Reported
	Catch (%)	Principal Location(s)	Principal Depth(s)	Principal Season(s)	Principal Gear(s)	Principal Habitat(s)	Fish < Lm (%) Sp	Su	Au	Perceived Stock Status	Stock Status
Top 10											
Siganus luridus	30.5	None	1m-50m	Sp, Su, Au	T, G	P, R	0.0	0.9	2.5	D ↑	No data
Oblada melanura	14.1	None	1m-25m	Sp, Su	G	P	0.0	0.0	0.0	F →	O ↓
Dentex macrophtalmus	12.0	Southwest	26-100m	Au	L	C	0.0	0.0	1.5	F →	F →
Sparisoma cretense	11.3	None	1m-50m	Sp, Su, Au	T, G	P, R	0.5	1.6	3.6	O ↓	No data
Serranus cabrilla	9.9	Southwest	26-100m	Au	L	C	87.5	26.7	39.6	O ↓	No data
Sepia officinalis	4.1	None	1m-25m	Sp, Su, Au	T	P	85.7	84.2	33.3	F →	F →
Pagellus bogaraveo	3.0	Southwest	51-100m	Au	L	C	No data	100.0	100.0	O ↓	O ↓
Scorpaena scrofa	2.9	None	1m-50m	Sp	T	P, R	1.1	11.8	0.0	O ↓	O ↓
Scorpaena porcus	2.1	None	1m-50m	Sp	T	P, R	0.0	9.1	0.0	O ↓	O ↓
Loligo vulgaris	1.2	None	1m-25m	Au	H	None	0.0	33.3	10.8	O ↓	O ↓
Top 15											
Diplodus vulgaris	1.0	None	1m-50m	Sp, Su, Au	T	P, R	27.8	50.0	60.0	O ↓	No data
Diplodus annularis	1.0	None	1m-25m	Sp, Su	T	P	19.2	20.0	83.3	O ↓	O ↓
Scomber japonicas	0.8	None	1m-25m	Su	G	None	0.0	11.5	100.0*	O ↓	O ↓
Symphodus tinca	0.8	None	1m-25m	Sp, Au	T	P, R	0.0	0.0	50.0	F →	No data
Mullidae sp.	0.7	Southwest	51-100m	Sp, Su, Au	T	C	0.0	0.0	0.0	O ↓	O ↓
Specified by FEK											
Sparus aurata	0.1	None	1m-50m	Sp, Su, Au	T, L	P, R, C	100.0	100.0	100.0	O ↓	O ↓
Dentex dentex	0.4	None	1m-50m	Sp, Su	T	P	35.3	33.3	0.0	O ↓	F →
Pagrus pagrus	0.3	Southwest	26m-75m	Sp, Su, Au	L	R, C	100.0	100.0	100.0	O ↓	O ↓

7.6 Discussion

In this chapter, interrogation of the characteristics of the Lipsi Small-Scale Capture Fishery (SSCF) adopted a triangulated approach, with the sector being interrogated utilising three complimentary techniques: Reported Fishery Data (RFD) from dockside conversations with fishers, Fishery Landings Data (FLD) from quantitative analysis of catch, and semi-structured interviews to elicit to fisher's perceptions and opinions - Fishers Ecological Knowledge (FEK). Through this approach, it has been possible to *characterise the fishery* based upon reported data and to report spatial fishing pressure.

In addition, through quantitative species *landings* and *bycatch* data it has been possible to quantify supply both abundance and richness of seafood products in the Lipsi SSCF and, finally, from interview it has been possible to elicit the perceived *temporal and spatial trends* of the Lipsi fisheries' productivity, through outreach to Fisher's Ecological Knowledge. Combined this data contextualises the amount of seafood extraction by the fishery; data relevant to the effective SSCM of the Lipsi SSCF to transition towards sustainability.

Presently, for Small-Scale Capture Fisheries (SSCF), Reported Fishery Data (RFD) is one of the only effective ways of collecting large quantities of data. Rarely do SSCF vessels have GPS trackers that will enable the tracking of fishing effort (although Vessel Tracking Systems (VTS) for artisanal fleets are becoming available for example http://www.pelagicdata.com). Furthermore, despite categorising gear types, often SSCF fishers may deploy multiple gear types in the same deployment e.g. a trammel net tied to a gill net, or deploy nets in such poor condition that the fishing effort would by drastically diminished from what a new net of the same type would achieve. Thus, when trying to *characterise* a SSCF, the true picture is inherently more complex than defining, for example, a LSCF. For this reason, simply asking fishers how, where and when they fish enables the collection of valuable contextual data.

The RFD in this chapter has engendered an understanding that the Lipsi SSCF seafood supply chain is stratified by depth in the marine environment, with seagrass meadows and rocky-algal habitats contributing most to the seafood supply chain in shallower (0m-50m) waters and coralline formations contributing the most in deeper (51m-100m) waters. This data has also highlighted that Lipsi SSCF fishers use a variety of gears to target a variety of seafood products making the Lipsi SSCF a multi-gear, multi species fishery.

In the Lipsi SSCF trammel and gill nets are principally used to target a larger variety (greater richness) of species in shallower waters / seagrass habitats and benthic longlines are generally used to target more specific species (particularly seabreams) in deeper water / coralline habitats. This data is essential for understanding habitat mediated seafood supply within the Lipsi SSCF and can be used to articulate Sustainable Supply Chain Management (SSCM) measures that ensure the continued provision of specific seafood products e.g. protect coralline habitats to ensure provision of *Pagrus pagrus* to the supply chain OR protect *Posidonia oceanica* seagrass to ensure the continuity of *Oblada melanura* supply.

In addition to the characterisation of the Lipsi fishery, RFD also enabled the mapping of fishing pressure by vessels from the Lipsi SSCF, and thus a better spatial understanding of fishing pressure. This again highlights that fishers do not treat the ocean or seas as homogenous entities, and that they will target specific 'fishing grounds' or 'fishing sites' which have traditionally provisioned better than average seafood products into their SSCF supply chains.

Of particular interest in this study, is the effect that the prevailing 'Meltemi' wind has on fishing effort around the south-east of Lipsi (the lee side of the island) and thus the logistical restrictions that are placed on fishers who at first glance might be assumed to have access to fishing across the Lipsi seascape. This limits the physical area of the marine environment that can be regularly targeted for extraction and thus contribute to the Lipsi SSCF supply chain.

Fisheries Landing Data (FLD) provides a robust, quantitative, approach for recording the richness, abundance and maturity of species that are landed by a fishery. Although inherently time consuming, landings data enables for species to be identified and their size measured to record whether the fish is being landed above or below its length at maturity (i.e. has it had a chance to reproduce). Furthermore, landings data can inform researchers of other elements that might be of interest to supply chain managers such as the prevalence of disease within a landed species, or the amount of predation on fishers catch from other marine animals (see Rios et al., 2017 for a Lipsi SSCF study). For these reasons, FLD provides essential quantitative information pertaining to the condition of seafood products flowing in the supply chain.

In this chapter FLD highlighted the extent to which the Lipsi fishery is multi-gear, multi-species SSCF, with four principal gear types being used to land 69 different species (seafood products) from 31 families during the surveyed fishing seasons (139 fishing trips). This data was also useful to highlight the heterogeneity of seafood product supply, the 10 most landed species constituted 85.2% of the overall landed catch.

What this means for informing Sustainable Supply Chain Management is that those 10 seafood products are going to have regular supply in comparison to the remaining 59 which are likely to experience more stochastic supply. Of major concern to this fishery is the prevalence of the Dusky Spinefoot (*Siganus luridus*) which appeared in fishers catch in over 7 in 10 trips, and represents nearly 1 in 3 of the fish caught by the Lipsi SSCF, the increasing dominance of this species in south-eastern Mediterranean seafood supply, and the impact of invasive species on the local food webs and biodiversity is presently a hot topic for research (see Galil 2007; Goren and Galil, 2008; Zenetos, 2010; Galil et al, 2015; Galil et al., 2016). Indeed, in contextualising the impact of these invasions Coll et al. (2008) found a high structural degradation in the Mediterranean food webs as compared to non-Mediterranean ecosystems. Yet this only reflects the ecological concerns and not the loss of revenue from landing fish that fetch low market price (see Chapter 9).
In addition to richness and abundance data, the FLD data also enabled identification of several key commercial species that were being landed below the length of maturity, notably these were esteemed species of food fish (e.g *Pagrus pagrus, Sparus aurata, Diplodus sargus, Sepia officinalis*) for which there is high demand in the supply chain due to their high economic value.

The Small-Scale Capture Fishery conceptual framework presented in this thesis enables the discussion and Sustainable Supply Chain Management of these seafood products by enabling articulation of the consumer demand, and product supply, by facilitating the expression of the interplay between demand created by consumers, and the extraction of seafood products by fishers from coastal habitats.

The role that Fishers' Ecological Knowledge can play in 'filling the gaps' of scientific knowledge is becoming increasingly accepted within segments of the marine research community, with several authors acknowledging that such knowledge is '*More than Anecdotes'* (Bevilacqua et al., 2016). In fact, fisher's knowledge can be a complement to conventional 'scientific' data and help improve the Sustainable Supply Chain Management of fisheries. Outreach to Fishers' Ecological Knowledge (FEK) (through a semi-structured interview) in this chapter enabled supply chain stakeholders to voice their perceptions of the temporal and spatial trends present in the fishery and to offer their suggestions on what SSCM initiatives could be introduced to make the supply chain more sustainable.

The fishers interviewed in this study were unanimous in their belief that the supply of fish had decreased in their lifetimes, and that poor management of the resource. In particular fishers believed that overextraction / overfishing was to blame for the current poor supply of seafood products entering the Lipsi SSCF supply chain. The fishers also perceived that across the Lipsi seascape product supply was lower now than it had been previously, whislt a few fishers were able to point to certain areas and habitats that they felt had been particularly degraded and / or overfished.

This data from the semi-structured FEK interviews lends weight both to the quantitative Fisheries Landings Data, which shows a paucity of larger commercial species (e.g. *Pagrus pagrus, Sparus aurata*) and an abundance of invasive species (e.g. *Siganus luridus*), but also to the trends and opinions expressed in other research into Greek seas which suggest that the seafood supply chain is being very poorly managed and that there is a crisis in the sustainability of seafood supply (Tsikliras et al, 2013; Moutopoulos et al., 2015).

7.6.1 Relevance to Small-Scale Capture Fishery Sustainable Supply Chain Management Conceptual Framework

This 'Fishery' chapter determined the characteristics of the Lipsi fishery, by defining its gear use, spatial fishing pressure and the extraction of species by abundance, richness and maturity. The data indicates that these coastal fish assemblages are in a dynamic state, and that for Sustainable Supply Chain Management (SSCM), close consideration needs to be paid to the heterogeneous distribution of these habitat-associated marine species.

With regards to the SSCM of the Lipsi Small-Scale Capture Fishery (SSCF), it is clear that fisheries supply chain managers need to consider seafood supply right through the first three stages of this SSCF Conceptual Framework: Habitat – Assemblage – Fishery. These three chapters have shown that the ecological system of the coastal zone around Lipsi is not homogenous, but is a seascape of various habitats that, whilst inter-connected, are unique in their characteristics. What this means for supply side provision is that certain habitats attract predictable species that aggregate to them, and thus will provision the supply chain with particular species assemblages. For SSCM, knowing the distribution (and ensuring the protection) of productive habitats is an essential first step in ensuring continuity of supply into the Lipsi SSCF supply chain.

This chapter also highlights the need to understand the sustainability of extraction with regards to the species that exist within an associated assemblage. Both the assemblage chapter and this fishery chapter has highlighted the 'fishing down' of the marine food web that has taken place in Greek waters and the need to ensure that those fish that are extracted are done so when fully mature. If managers are unable to enforce SSCM measures that protect juvenile fish then it is likely that further local extirpations (local extinctions) are likely to occur, further limiting the number of desirable seafood products that make their way to market through the Lipsi SSCF supply chain.

The data collected within this 'Fishery' chapter highlights some of the contrasts between SSCF SSCM and conventional Supply Chain Management. For example: in a conventional supply chain, it is likely that the flow of a product between supply chain stages would be regular, rather than variable and linked to the type, time and place of gear deployment. In addition, in a conventional supply chain, the way in which a product flows from the supplier is unlikely to have detrimental consequences on the capacity for future supply. The principal SSCM challenge relating to the SSCF identified in this chapter is the capacity for managers to enable the extraction of the desired products, from the desired suppliers, but without causing unsustainable harm to either the 'Habitat' or the 'Assemblage'. The methods involved in this extraction will be a trade-off linked to the capacity for a habitat to provision the desired product based on its a) product richness and b) product abundance.

Temporal challenges of extraction

The temporal trends reported by fishers presented in the Fishers Ecological Knowledge data suggest that the local Lipsi fishery is experiencing the same marine resource declines as elsewhere in Greece, highlighted by reports of declining catch (Tsikliras et al. 2007; Stergiou & Tsikliras 2011; Tsikliras et al, 2013; Moutopoulos et al., 2015). Lipsi fishers unanimously reported that since 'waypoints' in both 2000 and 2010, that the abundance of fish has been in decline. In fact, elder Lipsi fishers cited a local decline from as far back as 1990.

These trends are reflected elsewhere in the Greece, with Tsikliras et al (2013a) reporting that since 1995, there has been rapidly declining trends in landings across the country, and that such intense fishing has led to stock declines/collapses, to lower fish sizes, and to unsustainable exploitation levels. Numerous species categorized by Tsikliras et al (2013a) as "overfished" in Greece are currently being landed below their length of maturity and several species categorized as "fully exploited" may well be being exploited locally beyond sustainable levels. For example, the 81.3% of cuttlefish (*Sepia officinalis*) landed were below the length at maturity raising concerns of the exploitation of this stock. Particularly since over a decade ago it was thought to be nearing extraction rates close to the sustainable limit in the Mediterranean (FishBase, 2016).

The landings data was particularly concerning for the highly-esteemed food fish; the Greater amberjack (*Seriola dumerili*), the Red porgy (*Pagrus pagrus*) and the Gilthead seabream (*Sparus aurata*) with 100.0% of the seasons landed fish being below the length at maturity. This suggests that these local stocks are not "fully exploited" but "overfished", and thus in need of immediate stock management initiatives. Similar concerns can also be raised for a broad spectrum of other popular seafood species, particularly from the iconic Mediterranean seafood family of the seabreams (Sparidae) (Figure 148).

Figure 124. Due to their firm meat and silvery complexions the seabreams (Sparidae) have long been a popular food fish in the Mediterranean region.

Spatial challenges of extraction

The spatial trends reported by fishers presented in the Fishers Ecological Knowledge data suggest that one of the greatest spatial stratifications in seafood supply occurs with depth in the marine environment, specifically around the 50m depth contour that marks the change in benthic habitat from *Posidonia oceanica* seagrass and rocky-algal formations, to coralline algae reefs. Of key note is the distinct importance of all three habitats in supplying the seafood supply chain with popular seafood species. In contrast the areas un-vegetated sandy bottoms (at any depth) contribute little (by volume, or value) to the SSCF seafood supply chain.

Thus, to ensure sustainability of supply, it is these three complex habitats that must be prioritised for protection. The other striking spatial trend is the geographical distribution of fishing pressure around the south and east of the main island. Whilst much of this is linked to the location of the main Port (with its entrance facing south), the location of the port itself would likely have been in recognition of the prevailing etesian winds (the "Meltemi") which restricts the small-scale capture fleet to fishing activity on the sheltered leeside of the island.

For the Lipsi SSCF means restricted access to the shallow seagrass and rocky habitats surrounding the southern islets (e.g. Makronissi) in all but the strongest winds, but also, critically, access to the deepwater channel adjacent which lies adjacent (to the west) of these islets and to the south of 'Skafi' - Lipsi's highest point which stands at 277m above sea-level. (Figure 149).

Figure 125. A view south towards Makronissi (centre-left), and Fragos (right), from near the highest point on Lipsi (Skafi, 277m). Between Kimissi (the bay) and the islets are seagrass meadows and rocky-algal reefs (<50m), to the right is a deep-water channel of Coralline formations (>50m).

7.6.2 Management Recommendations

Ecosystem-based fisheries management (EBFM) has become the new standard in fisheries management (Pikitch et al, 2004), as modern management trends turn towards more holistic approaches of system "fisheries" (Hammer et al., 2003; Abesamis et al, 2006a). For effective EBFM, some authors have underlined the need for spatial indicators (Babcock et al., 2005) with few studies to date taking into account the spatial distribution of fishing effort prior to Marine Protected Area (MPA) creation (Cadiou et al., 2009). The subsequent spatial pattern of fishing effort is also crucial to evaluating any fisheries benefits after MPA creation (Stelzenmüller et al., 2008) and evaluative studies must be part of any follow up program to ensure the appropriateness and efficacy of any management initiatives here proposed. The allocation of fishing effort in small-scale fisheries can be influenced by many factors (Abesamis et al, 2006b), notably weather conditions (e.g. Lipsi's etesian winds) in conjunction with distance to fishing sites, as fishers seek higher yields. Local market demand for particular species (e.g, Lipsi restaurants demanding lobster) can also dictate fishing activity, directing fishers to target particular habitats (e.g. coralligène) using particular gears (longlines) at particular depths (>50m).

The increasing implementation of MPAs globally has been motivated by many objectives, among which the sustaining of small-scale and artisanal fisheries has been a prominent reason (Abesamis et al., 2006a). The positive impact of MPAs on surrounding fisheries is well documented, through spill over and larvae emigration (Abesamis et al., 2006b, Forcada et al., 2009; Stobart et al, 2009; Russ and Alcala, 2010). However, it is essentially to take the size of the proposed MPA into account, its design, the quality and extent of the habitat, and the mobility of the species it seeks to protect and enhance (Stelzenmüller et al., 2007; Claudet et al., 2008; Forcada et al., 2009). Management measures are highly place-specific, and thus the selection of an appropriate habitat mosaic (mixture of productive habitats) for protection is not just a matter for the ecological system (habitat and assemblage) but also for the social system (fishery and market).

The creation and sustainability of a protected area in Lipsi will need to consider the protection of both shallow (<50m), *Posidonia oceanica* and deep (>50m) corallagène algae ecosystems and the presence of rocky-algal reef structures that straddle both. The location of the chosen MPA most be both biologically logical, but also socially viable. This is important both for understanding the objectives of protecting a given area, but also in communication the expectation to stakeholders. For example, the protection of a small (50ha) area of coralline habitat may well allow for the recovery of a local Spiny lobster (*Palinurus elephas*) population, but it will do little to help the Swordfish (*Xiphias* gladius) population which would require the creation of a much larger marine reserve. The clear communication of these elements, when agreeing on reserve dimensions with stakeholders, is essential so that the expectations of reserve success are appropriate to both the time and spatial scale of reserve implementation. The uncertainties of reserve efficacy due to the effects of both regional scale drivers e.g. climate change, ocean acidification, regional overfishing, and due to the lack of a regional (Eastern Mediterranean) equivalent, must also be stated from the start.

Indeed, it is important to bear in mind some important characteristics of this small-scale fishery when seeking to implement management measures. These include the older age of fishermen (also reported in tropical fisheries; see de Camargo and Petrere, 2001), the family connected character of the profession; a characteristic typical of the production sector in Greece (Kalantaridis and Labrianidis, 1999) and the strong bonds with tradition (Tzanatos, 2006a). These affect both the fisherman's behaviour and tactics, which in turn affect fishing parameters such as selectivity, fishing effort allocation and production (Maury and Gasquel, 2001). These factors also influence the fishermen's opinion about management, usually making them more mistrustful and uncooperative with the fisheries authorities (Tzanatos, 2006a). The high number families of 'low income-high dependence' on the fishery means that the small-scale capture fishery still plays an important role in island life.

The small-scale fishery on Lipsi is a traditional activity and offers both local food security, and an important income for the local economy. Although a diversity of gears is seasonally deployed, the dominance in use of trammel nets is pronounced, a common pattern in Mediterranean coastal small-scale fisheries which targets multispecies catches and thus affects numerous species within an assemblage (Stergiou et al., 2002a; Stergiou et al., 2002b; Tzanatos et al., 2005; Tzanatos et al, 2006a; Tzanatos et al., 2006b). In the shallow (<50m) coastal waters of Lipsi, the principal caught species is the invasive Dusky spinefoot (*Siganus luridus*), although this varies seasonally with the Saddled seabream (*Oblada melanura*) prominent in later Spring, early Summer and the Mediterranean Parrotfish (*Sparisoma cretense*) consistently landed throughout. In the deeper (>50m) coastal waters, the principal caught species are the Comber (*Serranus cabrilla*) and the Large-eye dentex (*Dentex macropthalmus*). Emblematic species such as the Mediterranean slipper lobster (*Scyllarides latus*) and the European spiny lobster (*Palinurus elephas*) are also present in the catch, alongside principal catch species common elsewhere in the Mediterranean such as the Large red scorpionfish (*Scorpaena scrofa*) (Colloca et al, 2004; Cadiou et al, 2009; Stobart et al, 2009; Forcada et al, 2009).

Sustaining this small-scale fishing activity is one of the main objectives of the Lipsi Fishermen's Association, and for the Municipality of Lipsi, it is also a central activity in moving towards sustainable place creation. Small-scale fisheries like the fishery characterised in this chapter, meet most of the criteria for an enlightened fishery policy with regards to employment and income distribution, energy use and product quality (Pauly, 1997; Allison et al., 2001; Mathew 2003; Chuenpagdee, 201; Kittinger et al., 2013). Furthermore, the static gear small-scale fisheries (like Lipsi's fleet) have a lower impact on both habitat and assemblage integrity than their industrial counterparts, by generating fewer discards and having less impact on the habitat (Stobart et al, 2009.) Similar methods as those used here have also been used elsewhere in the Mediterranean to evaluate landings and fishing effort (Stelzenmüller et al., 2007, Cadiou et al, 2009), and separately to elicit temporal and spatial trends through outreach to fishers and local ecological knowledge (Coll et al, 2014). The data presented herein from this small-scale fishery combines these methods to create a 'snapshot' or cross-sectional study of a changing fishery. Whilst seasonal variation is fishing effort and technique has been elicited quantitatively (over the course of fishing season), no long-term quantitative data exists to map the fisheries production over the timescale of years to decades. For this reason, outreach to the Lipsi's fisher's ecological knowledge (sensu Coll et al., 2014), combined with regional (e.g. Tsikliras et al., 2013; Moutoupouls et al., 2015) and global trends (e.g. FAO, 2016) must inform the future direction of fisheries supply chain management.

7.6.3 Limitations and Future Research

The selection of research techniques used in this chapter represent a compromise, based upon time, cost and researcher capacity. As discussed, Reported Fishery Data is limited in that it relies on the truth being told to the researcher by participating fishers. If more funds were available, the use of VTS would be appropriate for the Lipsi Small-Scale Capture Fishery (SSCF) fleet given their limited number. Additionally, the provision of uniform fishing gears (e.g. same mesh size / length and hook size / number) would add consistency to the gear categories utilised here.

A further limitation, is the description of target habitat described by fishers. Nets can be >100m in length and therefore can easily cover a variety of habitat types – so is a fisher targeting seagrass meadows *actually* catching fish from within the seagrass meadows, or are they actually from the adjacent rocky-algal reef? Indeed, this both this data, and the data from the Assemblage chapter have shown that there is much overlap between the species assemblages associated to *Posidonia oceanica* seagrass meadows and Rocky-Algal habitat.

If further research was going to be conducted into this stage of the Lipsi SSCF supply chain, then it would be important to include the remaining full-time fishers that did not wish to participate in Fishery Landings Data. This is because fishery landings data relating to Lipsi's pelagic longline fishery is not represented in this chapters dataset, and yet the targeting of Swordfish (*Xiphias gladius*) does occur by at least one fisher in the Lipsi SSCF. Additionally, a greater amount of data would be achievable from outreach to Fishers Ecological Knowledge if this process was conducted by a researcher who was fluent in Greek.

CHAPTER 8 - Supply Chain Stage 4 - Market

8.1 Introduction

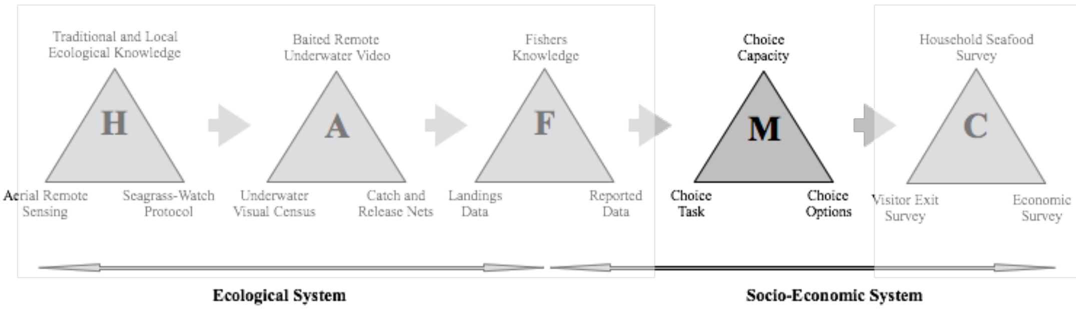

Figure 126. The Marketplace (M) is the fourth stage of the Small-Scale Capture Fishery supply chain. This supply chain stage is located within what would be conventionally conceptualised as the socio-economic system.

The fourth stage of the Small-Scale Capture Fishery Sustainable Supply Chain Management conceptual framework represents the market (or market*place*), broadly defined as a place where people gather to purchase and sell provisions, livestock and other goods or 'an area where commercial dealings are conducted' (Oxford Dictionary, 2016).

In the proposed 'Habitat to Consumer' conceptual framework, the marketplace may operate in the same physical space as the ecological 'place' under consideration. In fact, just like the 'place' of the ecological system, the market 'place' (socio-economic system) needs explicitly defining each time the framework is used, since it could realistically entail anything from a single retailer in one location, to the 'global marketplace'.

From a Sustainable Supply Chain Management (SSCM) perspective, the socio-economic context in which the Small-Scale Capture Fishery (SSCF) supply chain operates (the supply / demand and variety of products) can be better understood through interrogation of the market infrastructure (Choice Capacity), the variety of products available in the marketplace (Choice Task), and the way that seafood products are presented to the consumer (Choice Options).

Whilst much of what shapes a Market*place* is inherently linked to individual consumer preferences (Chapter 9), consumers have been deliberately considered in isolation so as to ensure identification of the characteristics of the Marketplace within the supply chain framework and so as to emphasise the Market as meeting point of multiple supply chains with origins in multiple places.

For the Lipsi fishery, providing such context can help supply chain managers to understand and articulate the reasons for the demand of certain species in the seafood supply chain, and facilitate discussion around the competition the Small-Scale Capture Fishery (SSCF) faces from competing seafood supply chains within the marketplace.

Together with the next chapter, a more holistic understanding of the demands placed on the Lipsi SSCF for the provision of specific seafood products can be articulated, and thus the pressures put on sustainable supply chain managers who need to balance long-term product supply with immediate product demand in an 'ecological dominant' manner (making decisions that prioritise the environment over everything else).

In this chapter, the 'Market'-*place,* as characterised by these three consumer 'choices' (Capacity, Task and Options), provides a richer picture of the mechanisms through which supply chains compete to provide seafood products to the end consumer. In conventional studies into small-scale fisheries, the demand for specific products has been explored through the lens of coupled social-ecological systems research (e.g. Cinner et al., 2006; McClanahan et al., 2009; McClanahan et al., 2011; Cinner et al., 2012; McClanahan et al., 2015)

Socio-economic studies

Over the last twenty years' socio-economic studies on fisheries have been met with worldwide interest (Farrugio et al, 1993; Allison et al., 2001; Béné 2006; Chupagdee, 2011; Jentoft et al., 2011; McClanahan et al., 2015), largely because they assist management measures (Tzanatos et al, 2006a; Tzanatos 2006b; Chupagdee 2011; Béné et al., 2016).

The Green Paper on the future of the Common Fisheries Policy (EC 2001) remarked on this increasing demand for socio-economic data and several EU studies have been carried out e.g. Farrugio et al, 1993; Tverteras and Lein, 2009; Brecard et al. 2009; Guyader et al., 2013. With notable studies being provided across the Mediterranean from Italy (Whitmarsh et al., 2003; Colloca et al, 2004), Spain (Garza-Gil 2003; Coll et al., 2014) and Greece (Stergiou et al., 2002; Tzanatos et al., 2006a; Tzanatos et al., 2006b). These Mediterranean studies mostly concern Small-Scale Capture Fisheries which is the sector (as opposed Large-Scale Capture Fisheries) with the highest number of participating fishers.

In addition, the level of regional dependence on fisheries has been examined in a series of studies (see Symes 2000), including, of interest here, some detailed work in Greece (Tzanatos et al., 2005) which characterised the Greek Small-Scale Capture Fishery fishers as:

"a complex system characterised by great spatio-temporal variation, diversity of gears and target species, scattering of fishing activity along the coastal zone and direct supply of the catch to the market."

Critical to the proposed conceptual framework for Sustainable Supply Chain Management (SSCM) of the Lipsi Small-Scale Capture Fishery (SSCF) is that the seafood products caught *directly* supply consumers who shop at the local Market *place*, and are therefore not part of an export orientated fishery that supplies consumers outside of place. It is already known that global marine fisheries are known to play a crucial economic, social and cultural role on fishing, processing and retail services (Dyck and Sumaila, 2010; FAO 2014), as well as in the provision of food security (Srinivasan et al, 2010) particularly in remote regions (Unsworth et al., 2010).

However, although SSCFs constitute a substantial component of seafood supply to these global fishery supply chains, the fisheries themselves remain data poor as well as economically and politically marginalised (Pauly, 1997; Allison and Ellis, 2001; Chuenpagdee, 2011; Béné et al, 2016). A lack of SSCF knowledge is recognised by the Food and Agricultural Organization and calls for further data generation through 'catch to market' research has been clearly articulated (FAO, 2007; Béné et al, 2016). In this chapter the role that the Lipsi SSCF has in directly contributing supply of the catch to the market will be articulated, as well as the highlighting the role that competition now plays between the seafood products it provides, with other 'imported' products now available in the marketplace.

Poverty reduction and food security are central to the world development agenda (Béné et al, 2016) e.g. Sustainable Development Goal 1 is "No Poverty" and Goal 2 is "Zero Hunger". However, the principal themes and challenges for local management are evolving heterogeneously in response to regional population trends, advances in technology and in response to regional changes in ecosystem services brought about by place-based environmental degradation and/or restoration. Recent discourse on food security has stressed the need for multiple political and socio-economic actions to address supply/demand challenges linked to adequate access of appropriate nutrition (Grafton et al, 2015).

However, the interplay between SSCF and other seafood products available is inherently place specific, with the choice capacity (supply chain infrastructure – what products are possible to present), choice task (product supply – what products to present) and choice options (product presentation – how to present the products) all playing a part in product availability in any given place. In general, these questions are considered under the umbrella term of 'Choice Architecture' (Figure 151). For SSCM of the Lipsi SSCF, understanding the place-based context of the local seafood supply chain is crucial for management decisions that are made upstream (i.e. habitat, assemblage, fishery).

Figure 127. Choice Capacity (Supermarket), Choice Task (Californian Squid), Choice Options (Red Tin) all play a part in 'Choice Architecture' and the influencing of consumer choice.

Choice architecture

Choice architecture, is often understood as the social background against which decisions are made (Sunstein and Reisch, 2014). This field of research explores the different ways in which choice can be presented to consumers, and the impact this has on consumer decision-making. For example, both the number of product choices available (Scheibehenne et al., 2010), and how those choices are presented (Larrick and Soll, 2008), will influence final consumer choice.

In Greece, this choice architecture is rapidly changing, as supermarkets expand their range, and as power-imbalanced relationships develop in food supply chains largely governed by this heightened retail power (Maglaras et al, 2015). These trends are not new, many developing countries are re-regulating their food markets around the imperatives of large supermarket chains (Cohen et al, 2013).

Supermarkets have amassed what Alexandra Hughes (1996) describes as a "hegemonic position in relation to other fractions of capital" and economists Reardon and Timmer have (2007) argued that;

"[m]arket led development is now supermarket-led development". But, as economists know well, supermarket chains do not simply expand or enhance market-led growth-they fundamentally restructure how food markets work and the legal, jurisdictional, and geographical scales on which they operate".

Indeed, the changes taking place throughout the world today reflect those that initially shaped the U.S. food supply system; specifically, 'the standardization and industrialization of agriculture, the demise of the small farmer… and the development of legal mechanisms to achieve these ends' (Cohen, 2013). Supermarkets have essentially reversed the way power flows in food supply chains, since they can now dictate what kinds of goods get produced, processed, manufactured, and sold. (Cohen et al., 2013). This process has enabled Supermarkets, as the most powerful party, to gain a higher proportion of the available benefits (Hoejmose et al., 2013).

Sector characterisation

In Greece, food supply chains have changed during the past decades, not least via the introduction of international manufacturers (e.g., Coca Cola Company, Unilever, Nestlé, Kraft Foods, Heineken) and retailers (e.g., Carrefour, Delhaize Le Lion, Lidl) (Marglas et al., 2015). Greek food retailing is highly concentrated with five retailers accounting for 56% of the grocery retail market (ICAP, 2013), and 'own brands' have grown rapidly to account for 20.7% of total grocery retail sales (ICAP, 2012). Overall, Greece has shifted from a 'traditional' to a 'modern' food supply chain (Marglas et al., 2015), and it can be expected that small and medium-sized suppliers will be comparatively disadvantaged when they deal with retailers (Blundel and Hingley, 2001) in this contemporary retail paradigm.

Within the Dodecanese archipelago, these changes were witnessed as the region's infrastructure developed in response to tourism growth and the need for improved logistics' and supply chain coordination. For Lipsi, the seafood market no longer means choice dictated by what the Lipsi Small-Scale Capture Fishery supplies, but what is available via imported products from several Mini-Markets. With the enhanced transport infrastructure consumers on Lipsi can be shopping in the supermarkets on neighbouring Patmos or Leros within 30 minutes or even in the regional hub of Kalymnos within 60 minutes.

For this reason, ‘Place’ relating to the Market infrastructure for Lipsi no longer means just the Municipality. Instead the ‘Market-*place*’ needs to be considered at a larger, regional, scale and is hereafter defined as the Marketplace of the northern Dodecanese (those islands accessible in 90mins from Lipsi).

The implications for the Lipsi SSCF, who exist on a “*direct supply of the catch to the* [local] *market”* (Tzanatos et al., 2005) are that the seafood products they supply to market are now in direct completion with other seafood products that have been imported from elsewhere. As such, they no longer have a monopoly of fish supply and consumers have the choice to ‘shop local’ or to purchase seafood products from around the world.

8.2 Aims and Objectives

This chapter focusses on establishing data pertaining to the traditional ‘catch to market’ elements of the Lipsi seafood supply chain:

1. What are retailers available to the people of Lipsi? (*Choice Capacity*)
2. What seafood products (species) are available at Market? (*Choice Task*)
3. How are these seafood products presented? (*Choice Options*)

Objectives

1. To identify the defining characteristics of the seafood Marketplace for the Municipality of Lipsi.
2. To identify what seafood products are presented to consumers and their place of origin.
3. To identify how these products are presented to the consumer

8.3 Materials and Methods

For a richer understanding of the Lipsi "Marketplace" (M) three elements have been chosen for consideration: 1) Choice Capacity, 2) Choice Task and 3) Choice Options (Figure 152). The presence of market infrastructure was recorded under the heading of 'Choice Capacity'. This represents the physical location and infrastructure for selling seafood products i.e. from the portside or from a supermarket. 'Choice Task' represents the documentation of the seafood products themselves i.e. what species are being sold and where are they are from. Finally, 'Choice Options' are recorded i.e. is the seafood product fresh, tinned or frozen?

Together these data characterise the Stage 4 – The Marketplace of the Small-Scale Capture Fishery Sustainable Supply Chain Management conceptual framework. It is this marketplace to which the Lipsi Small-Scale Capture Fishery supply chain supplies its products, and thus through interrogation of this that that context can be provided to supply chain managers in relation to product competition the SSCF supplied products face. This is done by documenting the types of retailers available, the presence of imported seafood products (species), or locally supplied products (species), and how they are presented. This is done at retailers across the islands of the Northern Dodecanese.

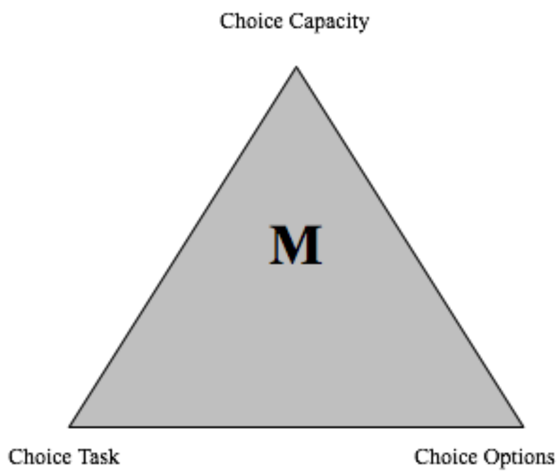

Figure 128. Marketplace (M), a triangulated approach has been adopted incorporating interrogation of Choice Capacity, Choice Task, and Choice Options

Defining 'place'

Market Surveys were conducted at fifty-one retailers, on the islands of Agathonissi, Arki, Marathi, Patmos, Lipsi, Leros, Kalymnos, Telendos and Pserimos (Figure 153). The isolated islands of Farmakonissi (10 residents) and Kalolimnos (2 residents) were excluded from survey due to logistics. All market surveys (outside of the Municipality of Lipsi) were conducted in August 2014. Therefore, this data represents a 'snapshot' in time during peak tourist season. This snapshot is useful (and timed accordingly) because some seafood retailers were only open for trade during the tourist season (≈April to ≈October, but primarily in June, July and August). The data obtained highlights the diversity of seafood products available in the northern Dodecanese's regional supply chains, and therefore the extent to which the global seafood trade is now present, and relatively accessible, to even the most remote Greek island communities.

Figure 129. The Northern Dodecanese archipelago showing islands for Market Survey.

All three elements pertaining to a retailer were established in a single visit. Upon identifying at a seafood retailer, the retailer was assigned to one of six retailer categories (see 9.3.1), their seafood product stock was documented (see 9.3.2) and the presentation of this stock recorded (see 9.3.3). Each island was surveyed from entering at the main (or one of the major) ports and working in a logical and stepwise direction until all major transport arteries had been surveyed. For smaller islands, or for islands with concentrated population centres (e.g. Pserimos, Telendos or Agathonisi) it was possible to survey the island on foot. For the larger islands of Leros and Kalymnos, a car was hired to drive between towns and villages.

8.3.1 Marketplace Infrastructure (Choice Capacity)

During exploration of each island, and upon identifying a seafood retailer, the exact location was marked on a map. This data was later transferred to Google 'My Maps' to ensure a digital copy of the locations of seafood retailers (Figure 154).

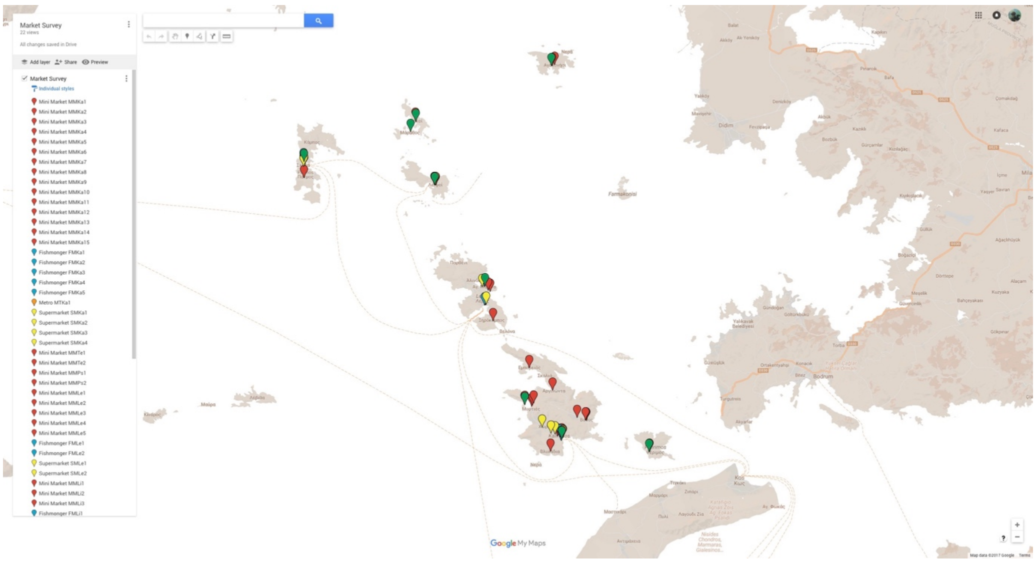

Figure 130. Market Survey data showing the location of all surveyed seafood retailers using Google™ 'My Maps'

Different retailers were numbered and colour coded for later identification: Fisher (Green) Fishmonger (Blue), Mini-Market (Red), Metro-Market (Orange) and Supermarket (Yellow). Restaurant locations were not recorded because they were sampled on a more ad-hoc basis. This was due to both the sheer volume and diversity of restaurants present on the islands.

Once the location of the seafood retailer was recorded, the retailer was assigned to one of six retailer categories that best reflected their retail infrastructure. Fishers were used to describe seafood supply straight from the boat or from portside tables. Fishmongers were those whose dominant trade was in that of fresh local fish (although some also supplemented stock with imports and frozen produce).

Mini-Markets were characterised by the retail environment, the presence of a more formalised 'shop' selling a variety of tinned and frozen goods, and a Metro-Market was similar, except that it was a shop that belonged to one of the large supermarket 'chains'. Finally, a supermarket, was defined by its size, as a large retail outlet. These were almost exclusively part of larger national or international chains.

A photo of each the six seafood retailers can be seen in Table 52. A brief description of retailer's dominant characteristics.

1. **Fishermen (CF):** sell local produce directly to consumers, either from their vessels, the quayside or from quayside stalls. All seafood was caught locally by the SSCF using the variety of gears outlined in Chapter 7.

2. **Restaurant (RE):** characterized by the selling of fresh local seafood supplied by the SSCF and often supplement by selling a few high value imported species (e.g. *Salmo salar,* Penaeidae prawns) and locally produced aquaculture species Sea Bass (*Dicentrachus labrax*) and Gilthead Sea Bream (*Sparus aurata*).

3. **Fishmongers (FM):** broadly characterized by the same produce range as restaurants, but differentiated by the supply of high abundance, low value species such as the Dusky spinefoot (*Siganus luridus*) and Garfish (*Belone belone*).

4. **Mini Markets (MM):** characterized as being independent retailers (non-chain) usually selling tinned and / or frozen seafood. Therefore, the seafood sold was a mixture of both imported and nationally sourced produce that had been processed for retail.

5. **Metro Markets (MT):** characterized as being smaller outlets of larger branded supermarket chains. Metro Markets often sold frozen and tinned seafood (similar to Mini-Markets) but also some high value fresh fish.

6. **Super Markets (SM):** characterized as larger market stores. They were either independent or part of large national/international chains. Like Metro-markets they often sold 'fresh', frozen and tinned seafood.

Table 39. A typology of retailer's characteristic of northern Dodecanese.

(1)
Fishers

(2)
Restaurants

(3)
Fishmongers

(4)
Mini-Markets

(5) Metro-Markets	
(6) Super-Markets	

8.3.2 Product Availability - Choice Task

Once a seafood retailer had been assigned a retailer category, and thus the ‘Choice Capacity’ had been established, the next step was to record the variety (richness) of species that were presented to the consumer. This is ‘Choice Task’, what are the species that being presented to the consumer and therefore how big is the task of choosing between the varieties of species presented. If there is only one product (species) available, then Choice Task is simple, however if there are a multitude of seafood products (species) to choose from (some of which may be very similar) then ‘Choice Task’ is made much more difficult.

Of concern to informing the Sustainable Supply Chain Management (SSCM) of the Lipsi Small-Scale Capture Fishery (SSCF) is the designation of origin of the seafood products. This is because if a local fish species is overfished, then the species may be able to be ‘substituted’ by supply chain managers with a similar imported species e.g. the *imported* West African Goatfish (*Pseudupeneus prayensis*) can be substituted for the *local* Surmullet (*Mullus surmulletus*) since the two species are physically very similar (Figure 155). Such ‘species substitution’ can help to reduce the pressure on overfished stocks.

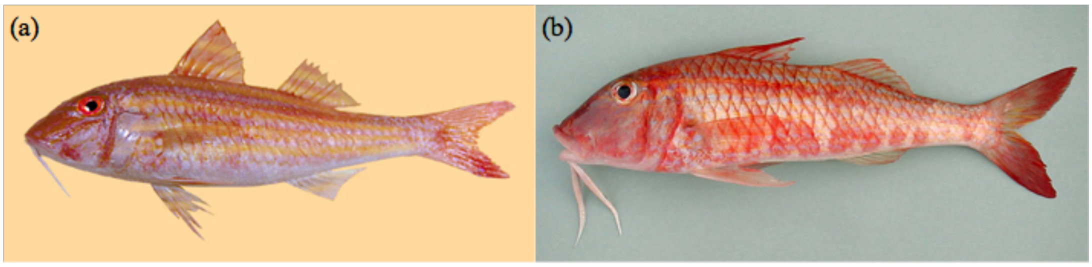

Figure 131. Declines in the supply of (a) the local Surmullet (*Mullus surmulletus*) are not a concern to consumer is they can be replaced with supply (b) of the West Afican Goatfish (*Pseudupeneus prayensis*), a similar species from the same Family (Mullidae). FishBase (2016).

Once the seafood products (species) present at retailers have been identified they were analysed using three factors to establish geospatial patterns in seafood supply;

a. Region of origin: Defined as Mediterranean (M), International (I) Both (B)
b. Ocean of origin: Defined by the UN FAOs Major Fishing Areas (Figure 156)
c. Continent of origin: Defined by countries as recognised by the United Nations.

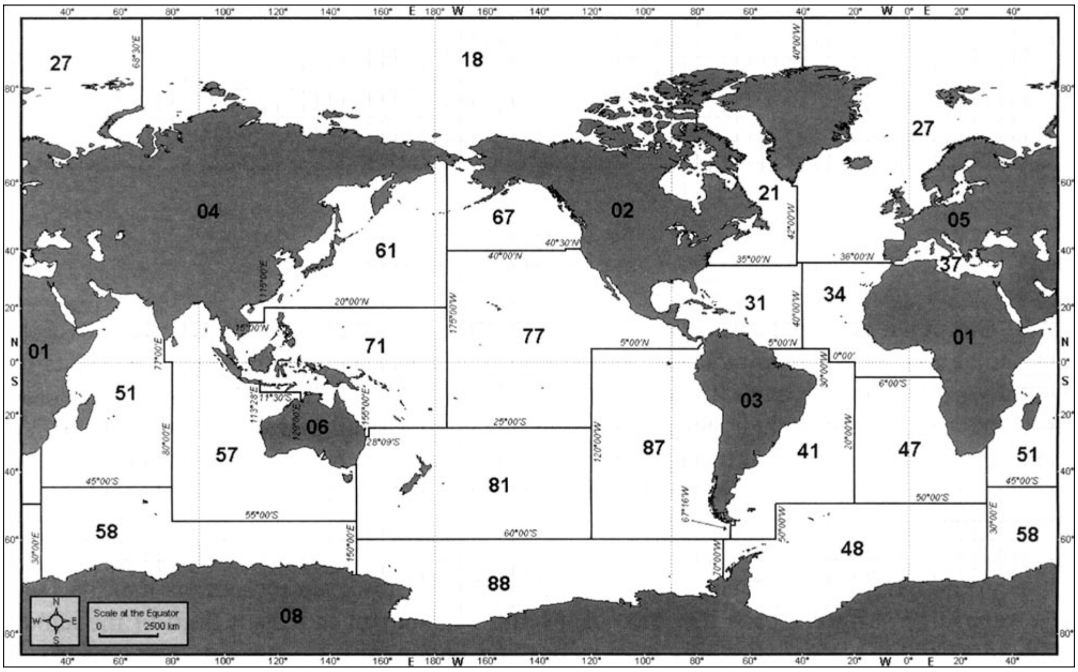

Figure 132. The Major Fishing Areas of the United Nations Food and Agricultural Organisation (Image: FAO.org).

Proximity: Greece (G) is defined as the 114, 394km^2 of territorial waters (~ constituting waters between 34° - 42° North, and 19° - 30° East, in the Mediterranean Sea). The Mediterranean (M) is defined as the 2,987,897km^2 of fishing area of FAO Region 37 (Caddy et al.,1998)**.** International (I) is defined as the 355,447,664km^2 of fishing area or the remaining FAO Regions (minus the Mediterranean).

Major Fishing Area: The Major Fishing Areas are those determined by the FAO of the UN. Of note is the relatively small size (2,987,897km^2) of the Mediterranean and Black Sea (FAO 37), in comparison with the other regions (mean = 19,747,092km^2). The total global surface fishing area is 358,435,561km^2.

Country of origin: Seafood products are sometimes labelled with the name of the country of origin. These countries are considered 'exporters' of the seafood product whereas Greece would be referred to as the 'importer' the seafood products.

Understanding where in the world seafood products are being supplied from is important for Sustainable Supply Chain Managers who need to predict the long-term sustainability of imported seafood supply. Whilst supply chain managers in Greece might not be able to control the seafood provisioning of distant habitats into distant fisheries, they can at least make informed decisions about the sustainability of seafood from 'import' supply chains by using the conceptual framework and asking questions such as; Are the provisioning habitats of those regions supplying the seafood being managed? Is overfishing occurring? Does conflict threaten supply?

8.3.3 Product Presentation (Choice Options)

The final stage in the Market Survey method is in categorizing the seafood products present into their 'Choice Options'. In this context 'Choice Options' relates to how the species that are being sold are presented to consumers. For example, is the Seabream (*Sparus aurata*) being sold fresh or refrigerated, is the Salmon (*Salmo salar*) being sold refrigerated or canned? When faced with the same species, but presented in a numer of different ways, the consumer has to make yet another decision over what seafood to purchase. Of concern to SSCM is the packaging of the seafood products across four categories; (1) Fresh, (2) Chilled, (3) Frozen, and (4) Canned. A photo of each of the categories is in Table 53 and a brief description:

1. **Fresh (H):** which generally implies that the seafood products are in the same state as when they were harvested. For larger marine species (e.g. swordfish) they may have been partially processed (i.e. cut into steaks) but otherwise they remain unmodified.

2. **Refrigerated (R):** seafood produce that has generally been processed to enable presentation to the consumer as chilled or refrigerated. This includes those in plastic packaging, glass jars etc or those presented dried or pickled.

3. **Frozen (F):** which generally means seafood that has been processed and frozen prior to being presented to consumers in plastic packaging or box for home storage in freezers.

4. **Canned (C):** which generally involves canning to preserve the products in an airtight container, providing a longer shelf life for products allowing them to be transported over long distances and stored for future consumption.

Table 40. A typology of seafood products presented to consumers.

(1) Fresh	

(2)
Refrigerated

(3)
Frozen

(4)
Canned

8.4 Data Analysis

Market Survey seafood product data was categorised into 1 of 6 groups of retailers for ‘Choice Capacity’; (Fisher, Restaurant, Fishmonger, MiniMarket, MetroMarket, SuperMarket). For Choice task, typology was delineated into 1 of 3 groups based upon proximity, and one of 19 groups based upon the FAOs Major Fishing Areas, and 1 of 193 counties based upon those recognized by the UN. Finally, products were also classified based upon product presentation into 1 of 4 groups, this represented the Choice options. All mean summary statistics were calculated with their standard error.

8.5 Results

Market Surveys were conducted on nine islands of varying size ($2km^2$ to $111km^2$) and infrastructural development in the northern Dodecanese as per Table 55

Table 41. A table highlighting the characteristics of the nine islands surveyed during Market Survey

Island	Code	Population	Area (km²)	Port	Airport
Agathonissi	Ag	185	13	Yes	No
Arki	Ar	50	7	Yes	No
Marathi	Ma	10	2	No	No
Lipsi	Li	600	17	Yes	No
Patmos	Pa	3000	34	Yes	No
Leros	Le	7900	54	Yes	Yes
Kalymnos	Ka	17000	111	Yes	Yes
Telendos	Te	40	3	No	No
Pserimos	Ps	130	5	Yes	No

Results revealed a total seafood product availability of 153 species, from 59 families across the northern Dodecanese archipelago. This represents 221.7% the species availability that is available from the Lipsi Small-Scale Capture Fishery alone.

The species identified by Chapter 7 landings data (69 species, 33 families,) have been utilized in this chapter as a catch proxy for other Small-Scale Capture Fishery fleets in the northern Dodecanese archipelago and on this basis the range in seafood product availability ranges from 71 species on the smallest island of Marathi and Pserimos to 137 species on the largest island of Kalymnos. The larger islands (Patmos, Leros and Kalymnos) offered the consumer a greater variety of retailer and of products (Figure 157).

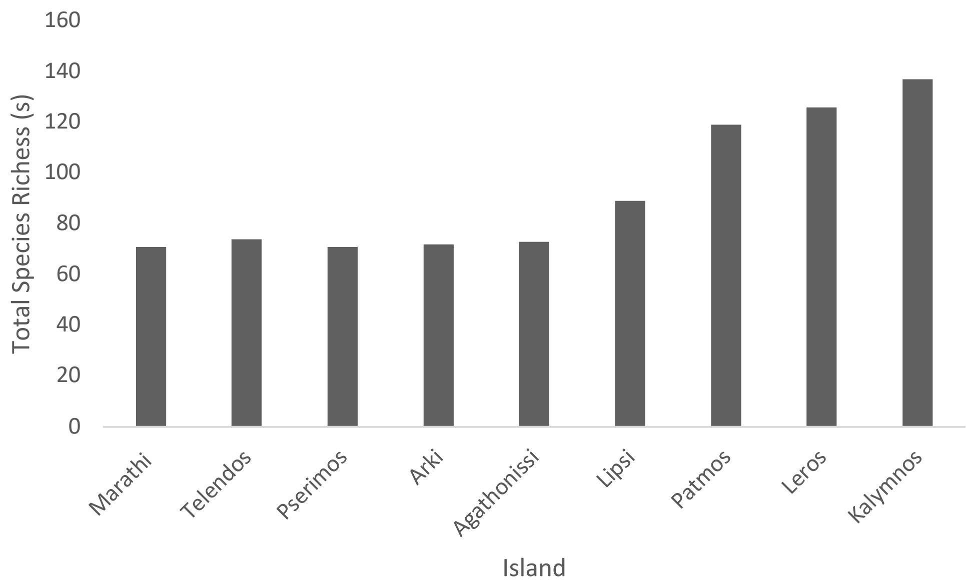

Figure 133. The total number of different species recorded on each of the nine islands. A greater variety of species were recorded as available to the consumer on the larger islands compared to the smaller islands.

Across the northern Dodecanese, the modernisation ('internationalisation' and 'supermarketisation') of supply chains is currently underway (Marglas et al., 2015), but to varying degrees based upon island size and supporting infrastructure.

Whilst consumers can purchase seafood directly from (1) fishers on every island, the presence (or absence) of (2) restaurants, (3) fishmongers and (4) mini-markets will directly influence the choice architecture by determining the species of seafood available (e.g. imported / local). On the largest islands, where large retailers have (5) Metro-market and (6) Supermarket 'chain' stores, the choice architecture is markedly different again with a wide range of imported seafood available to consumers.

This greater variety of seafood products can be linked to the greater numbers of Mini-Markets and Metro-Markets on these islands, and also to the presence of Super-Markets; which greatly increased the variety of imported seafood products available to consumers (Table 55).

In contrast, the smallest islands, had less (if any) retail infrastructure. Here the seafood product supply chains were often limited to what the resident fishers had caught and could either be purchased directly from the dock or cooked in a Taverna (traditional Greek restaurant). The photos in Figure 158 are indicative of the markedly different population sizes that are present between islands. These demographics have resulted in contrasting supply and demand challenges, and thus Sustainable Supply Chain Management challenges, for seafood produce across the northern Dodecanese island group.

Figure 134. (a) Kalymnos (*population* 17,000) and (b) Arki (*population* 50) illustrating the very different population pressures present on different islands.

Small-scale fishers and restaurants were present on all 9 islands, fishmongers were only present on the 4 largest islands. Mini-Markets were present on all islands but the very smallest (Marathi), although these varied in size and scale between islands. Metro-Markets and Super-Markets were only present on the four largest islands.

Table 42. Market surveys were conducted across nine of the northern Dodecanese islands, recording the variety of seafood products available for consumption (NB – Islands presented ranked according to size; smallest to largest island).

Island (km^2)	Retailer Type	No of Retailers (n)	Families (n)	Species (n)
Marathi (2)	Fishers	3	33	69
	Restaurant	3	15	37
Telendos (3)	Fishers	3	33	69
	Restaurant	6	16	38
	Mini Market	2	3	3
Pserimos (5)	Fishers	3	33	69
	Restaurant	5	16	38
	Mini Market	2	0	0
Arki (7)	Fishers	4	33	69
	Restaurant	2	15	37
	Mini Market	1	2	2
Agathonisi (13)	Fishers	10	33	69
	Restaurant	4	16	38
	Mini Market	2	2	2
Lipsi (17)	Fishers	10	33	69
	Restaurant	11	24	47
	Fishmonger*	1	2	2
	Mini Market	3	5	8
	Metro Market	1	3	5
Patmos (34)	Fishers	>30	33	69
	Restaurant	>50	26	54
	Fishmonger	2	11	19
	Mini Market	4	8	12
	Metro Market	1	14	21
	Super Market	2	20	37
Leros (54)	Fishers	>60	33	69
	Restaurant	>30	26	54
	Fishmonger	2	13	23
	Mini Market	5	10	20
	Super Market	2	21	40
Kalymnos (111)	Fishers	>100	33	69
	Restaurant	>50	27	58
	Fishmonger	5	20	35
	Mini Market	15	11	22
	Metro Market	1	4	6
	Supermarket	4	21	51

Cluster analysis showed differentiation between seafood product availability across each of the islands (Figure 159a). Here the three biggest islands are markedly different both from Lipsi, and from the other five islands.

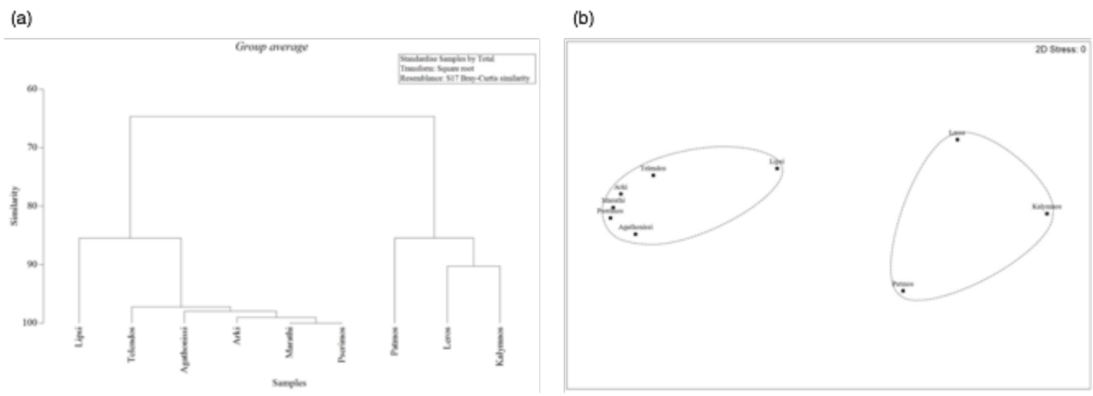

Figure 135. (a) Cluster analysis (b) nMDS ordination showing the similarities of seafood products available to consumers on each of the nine islands

To better highlight these similarities, superimposed Bray-Curtis clusters on nMDS ordination are presented in Figure 159b. The two clusters (at the 85% level) show that whilst Lipsi is more similar to the smaller five islands in terms of the products it offers. However, it differs from these islands too with seafood products available here that are also available on the largest three islands.

In addition to the Small-Scale Capture Fishery (SSCF) seafood products, a further 83 species from 32 families were recorded in the Market Survey. Notably this included 13 species from the family Scombridae (Mackerels, Tunas and Bonitos), 12 species from the Penaeidae (Prawns) and 7 species from the Clupeidae (Herrings and Sardines).

Four species of Loliginidae (Pencil squids) and four species of Ommastrephidae (Arrow squids) as well as unspecified species of Octopodidae (Octopus) were also imported, this is notable because of the cultural importance of these seafood products in traditional 'Mezedhes' (see Chapter 9).

All the 'non-SSCF' fishery species recorded in the marketplace are presented in Table 56.

Table 43. A list of all non-Small-Scale Capture Fishery species available at Market.

Family	Species	English
Anoplopomatidae	*Anoplopoma fimbria*	Black cod
Clupeidae	*Clupea harengus*	Atlantic herring
Clupeidae	*Clupeonella cultriventris*	Black Sea sprat
Clupeidae	*Scomber colias*	Chub mackerel
Clupeidae	*Sardina pilchardus*	European pilchard
Clupeidae	*Sprattus sprattus*	European sprat
Clupeidae	*Sardinella gibbosa*	Goldstripe sardinella
Clupeidae	*Sardinella aurita*	Round sardinella
Engraulidae	*Engraulis encrasicolus*	European anchovy
Gadidae	*Gadus chalcogrammus*	Alaska pollock
Gadidae	*Melanogrammus aeglefinus*	Haddock
Gadidae	*Gadus morhua*	Atlantic cod
Gadidae	*Gadus macrocephalus*	Pacific cod
Latidae	*Lates niloticus*	Nile perch
Lithodidae	*Paralithodes californiensis*	King crab
Loliginidae	*Loligo vulgaris*	European squid
Loliginidae	*Uroteuthis duvaucelii*	Indian squid
Loliginidae	*Doryteuthis opalescens*	Opalescent inshore squid
Loliginidae	*Loligo gahi*	Patagonian squid
Merlucciidae	*Merluccius hubbsi*	Argentinean hake
Merlucciidae	*Merluccius merluccius*	European hake
Moronidae	*Dicentrarchus labrax*	European seabass
Mullidae	*Pseudupeneus prayensis*	West African goatfish
Mytilidae	*Perna viridis*	Asian green mussel
Mytilidae	*Mytilus edulis*	Atlantic blue mussel
Mytilidae	*Mytilus chilensis*	Chilean mussel
Mytilidae	*Mytilus galloprovincialis*	Mediterranean mussel
Mytilidae	*Perna canalicula*	New Zealand greenshell mussel
Nemipteridae	*Nemipterus virgatus*	Golden threadfin bream
Nephropidae	*Homarus americanus*	American lobster
Nephropidae	*Homarus gamarus*	European lobster
Octopodidae	*Octopus vulgaris*	Common octopus
Octopodidae	*Eledone moschata*	Musky octopus
Ommastrephidae	*Todarodes pacificus*	Japanese flying squid
Ommastrephidae	*Nototodarus sloanii*	New Zealand arrow squid
Ommastrephidae	*Dosidicus gigas*	Humboldt squid
Ommastrephidae	*Illex argentinus*	Argentine shortfin squid
Pangasiidae	*Pangasius hypophthalmus*	Iridescent shark
Parechinidae	*Paracentrotus lividus*	Purple sea urchin
Pectinidae	*Pecten maximus*	King scallop
Penaeidae	*Penaeus kerathurus*	Carramote prawn

Penaeidae	*Penaeus monodon*	Giant tiger prawn
Penaeidae	*Penaeus semisulcatus*	Green tiger prawn
Penaeidae	*Fenneropenaeus indicus*	Indian prawn
Penaeidae	*Parapenaeopsis stylifera*	Kiddi shrimp
Penaeidae	*Penaeus notialis*	Southern pink shrimp
Penaeidae	*Penaeus schmitti*	Southern white shrimp
Penaeidae	*Litopenaeus vannamei*	Whiteleg shrimp
Penaeidae	*Metapenaeus affinis*	Jinga shrimp
Penaeidae	*Metapenaeus dobsoni*	Kadal shrimp
Penaeidae	*Metapenaeus monoceros*	Speckled shrimp
Penaeidae	*Metapenaeopsis stridulans*	Fiddler shrimp
Pleuronectidae	*Limanda aspera*	Yellowfin sole
Pleuronectidae	*Pleuronectes platessa*	European plaice
Portunidae	*Callinectes sapidus*	Chesapeake Blue crab
Portunidae	*Charybdis feriatus*	Crucifix crab
Portunidae	*Carcinus aestuarii*	Mediterranean shore crab
Salmonidae	*Salmo salar*	Atlantic salmon
Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon
Salmonidae	*Oncorrynchus mykiss*	Rainbow trout
Salmonidae	*Oncorhynchus keta*	Chum salmon
Sciaenidae	*Argyrosomus regius*	Stone bass
Scianidae	*Sciaena umbra*	Brown meagre
Scomberesocidae	*Cololabis adocetus*	Saury
Scombridae	*Thunnus alalunga*	Albacore tuna
Scombridae	*Thunnus thynnus*	Atlantic bluefin tuna
Scombridae	*Sarda sarda*	Atlantic bonito
Scombridae	*Scomber scombrus*	Atlantic mackerel
Scombridae	*Thunnus obesus*	Bigeye tuna
Scombridae	*Auxis rochei*	Bullet tuna
Scombridae	*Euthynnus alleteratus*	Little tunny
Scombridae	*Scomber australasicus*	Pacific mackerel
Scombridae	*Katsuwonus pelamis*	Skipjack tuna
Scombridae	*Sarda chiliensis*	Pacific bonito
Scombridae	*Thunnus albacares*	Yellowfin tuna
Scombridae	*Thunnus tonggol*	Longtail tuna
Scombridae	*Rastrelliger brachysoma*	Short mackerel
Sebastidae	*Sebastes mentella*	Redfish
Sebastidae	*Sebastes marinus*	Rose fish
Serranidae	*Epinephelus aeneus*	White grouper
Solenoceridae	*Pleoticus muelleri*	Argentine red shrimp
Sparidae	*Pagrus major*	Japanese seabream
Sparidae	*Diplodus puntazzo*	Sharp-snout seabream
Tellinidae	*Peronaea planata*	Mediterranean tellin clam
Veneridae	*Paphia undulata*	Undulated surf clam

8.5.1 Marketplace Infrastructure (Choice Capacity)

Market Survey data revealed mean seafood product species richness to be highest from the SSCF fleets with 69 species recorded. Supermarkets offered the second highest level of consumer choice with 42.7 (±4.3) species available to consumers followed by Restaurants which offered 26.3 (±4.5) species. Metro Markets, Mini Markets, and Fishmongers offered the least variety of seafood species at 10.7 (±5.2), 9.9 (±3.2) and 8.8 (±4.6) respectively (Figure 160).

For a Small-Scale Capture Fishery context Kalogirou et al. (2010) reported 88 species from 34 families from his boat seining study in 2008 which are not dissimilar to the Small-Scale Capture Fishery data recorded in this study (Note: (i) not all of the species they recorded would enter the seafood supply chain and (ii) the fishing gear they used is less selective).

However, for the other retailers, there is no directly comparative metadata available. Other research exists that model's decisions related to the purchase of food products and the spatial orientation of the retailer in question (Smith, 2004; Erdem et al., 2003; Hendel and Nevo, 2006; Markley, 2007).

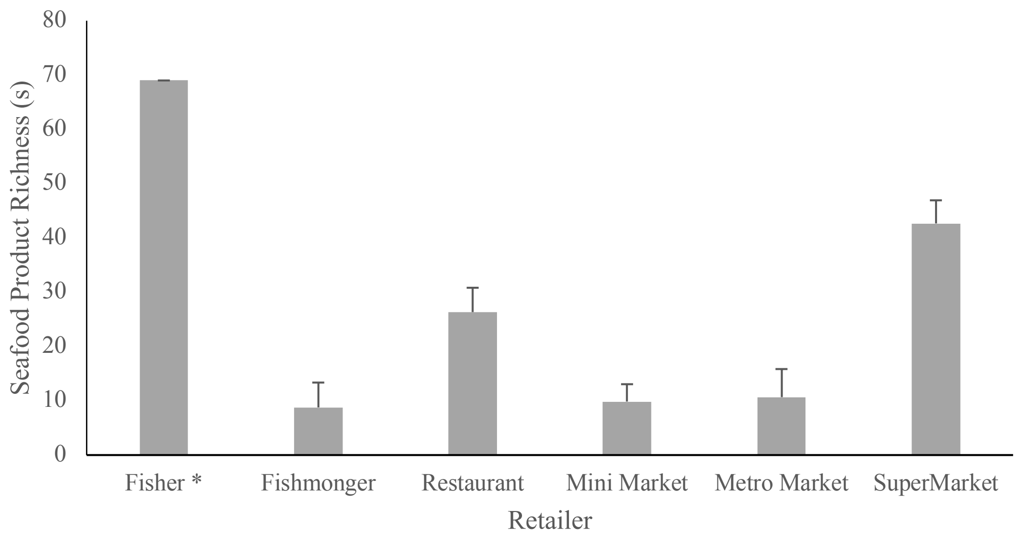

Figure 136. Mean (±SE) seafood product species richness available at each of the six types of seafood product retailer. * represents the proxy figure of 69 species for all islands (recorded in Chapter 7 from the Lipsi Small-Scale Capture Fishery).

In general seafood from the SSCF is either consumed at home, sold directly to consumers for local consumption or sold to one of the regions ‘fresh fish’ retailers; fishmongers or restaurants (see Chapter 9 for consumption data). In contrast to this, mini-markets, metro-markets and super-markets generally offered produce that was more likely to have been imported or in some way processed.

Cluster analysis showed differentiation in product availability across retailer types (Figure 137a). Here the traditional retailer supply chain of fisher, fishmonger and restaurant were the most similar in the products they offered, with seafood species available from the SSCF, supplemented by others sourced from elsewhere. In comparison, the products available from Mini-Markets and Metro-Markets were very different and these were different again to those that could be obtained from Supermarkets (Figure 161b).

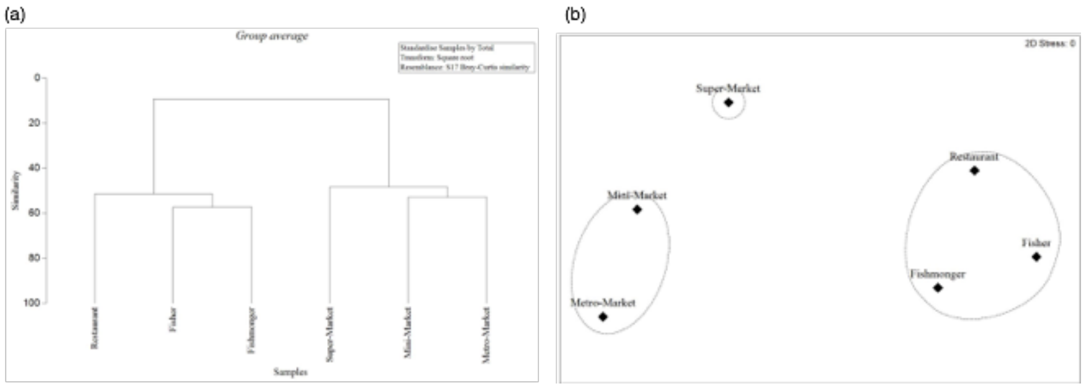

Figure 137. (a) Cluster analysis (b) nMDS ordination showing the similarities of seafood products available to consumers from each of the six retailer types.

For example, the Fishmongers on Patmos stocked European Seabass (*Dicentrarchus labrax*) which was purchased along with Gilthead seabream (*Sparus aurata*) from the fish farm on Leros (http://www.markellosmarine.gr).

Swordfish was also available (Figure 163) (*Xiphias gladius*) which was caught by small-scale fishers deploying pelagic longlines. On Leros, in addition to the usual seabream and seabass, farmed species of Stone Bass (*Argyrosomous regius*), Sheephead Bream (*Puntazzo puntazzo),* Japanese Seabream (*Pagrus major*) and Common dentex (*Dentex dentex*) were also available. Additionally, one fishmonger was also selling Dusky grouper (*Epinephelus marginatus*) (obtained from spearfishing) and a Bluefin tuna (*Thunnus thynnus*) (Figure 138). Fishmongers also stocked imported frozen prawns (Penaediae) and smaller pelagic species such as European Anchovy (*Engraulis encrasicolus*) and European Sardine (*Sardina pilchardus*) which are not generally targeted by the SSCFs.

Figure 138. A Swordfish (*Xiphias gladius*) caught by the Patmos Small-Scale Capture Fishery after deploying pelagic longlines. (NB - There are a couple of boats that deploy pelagic longlines on Lipsi, but they did not participate in the fishery landings).

In contrast, the category of ‘Restaurant’ represents a broad typology; from the humble Taverna (selling the day’s catch) to the large tourist restaurants that catered to international tastes (Figure 139).

Figure 139. Restaurants were anything from (a) simple family taverna’s to (b) larger scale hotel and restaurant complex’s.

On the islands of Marathi and Arki only tavernas were present with seafood from the islands’ SSCFs. Similarly, on Aganthonissi, Telendos and Pserimos, the only species for sale not directly available from the SSCF, was the European Seabass (*Dicentrarchus labrax*). However, on the three larger islands, with the greatest number of residents and tourists, a greater variety of imported species were available. The non-small-scale fishery species recorded on each of the islands is presented in Table 57.

Table 44. Non-Small-Scale Capture Fishery seafood products recorded from restaurants on each of the four larger islands. (*) whilst recorded in the SSCF landings, the majority of Gilthead seabream (*Sparus aurata*) and European seabrass (*Dicentrarchus labrax*) for sale in restaurants are not from the SSCF but are instead from local fish farms. Some restaurants will specify the origin of their seabream "wild caught" or "farmed". Consumers pay a premium for a wild caught fish.

Island	Island Import	Greek Aquaculture	Other Capture Fishery
Aganthonissi	-	**European seabass*** (*Dicentrarchus labrax*) **Gilthead seabream*** (*Sparus aurata*)	-
Arki	-	-	-
Marathi	-	-	-
Lipsi	**European hake** (*Merluccius merlucius*) **Atlantic cod** (*Gadus morhua*) **Blue mussel** (*Mytilus edulis*) **European lobster** (*Homarus gamarus*) **Rainbow trout** (*Oncorrynhchus mykiss*) **Giant tiger prawn** (*Penaeus monodon*) **Atlantic salmon** (*Salmo salar*)	**European seabass*** (*Dicentrarchus labrax*) **Gilthead seabream*** (*Sparus aurata*)	**Purple sea urchin** (*Paracentrotus lividus*)
Patmos	**Black cod** (*Anoplopoma fimbria*) **Atlantic cod** (*Gadus morhua*) **European lobster** (*Homarus gamarus*) **American lobster** (*Homarus americanus*) **European hake** (*Merluccius merlucius*) **Blue mussel** (*Mytilus edulis*) **Mediterranean mussel** (*Mytilus galloprovincialis*) **Rainbow trout** (*Oncorrynhchus mykiss*) **California king crab** (*Paralithodes californiensis*) **Giant tiger prawn** (*Penaeus monodon*) **Atlantic salmon** (*Salmo salar*) **Mediterranean tellin clam** (*Peronaea planata*)	**European seabass*** (*Dicentrarchus labrax*) **Gilthead seabream*** (*Sparus aurata*)	**Purple sea urchin** (*Paracentrotus lividus*) **Goldblotch grouper** (*Epinephelus costae*) **Dusky grouper** (*Epinephelus marginatus*) **White grouper** (*Epinephelus aeneus*)

Leros	**Mediterranean shore crab** (*Carcinus aestuarii*) **Atlantic cod** (*Gadus morhua*) **European lobster** (*Homarus gamarus*) **European hake** (*Merluccius merlucius*) **Blue mussel** (*Mytilus edulis*) **Mediterranean mussel** (*Mytilus galloprovincialis*) **Rainbow trout** (*Oncorrynhchus mykiss*) **California king crab** (*Paralithodes californiensis*) **Giant tiger prawn** (*Penaeus monodon*) **Carramote prawn** (*Penaeus kerathurus*) **Mediterranean tellin clam** (*Peronaea planata*)	**European seabass*** *(Dicentrarchus labrax*) **Gilthead seabream*** (*Sparus aurata*)	**Purple sea urchin** (*Paracentrotus lividus*) **Goldblotch grouper** (*Epinephelus costae*) **Dusky grouper** *(Epinephelus marginatus)* **White grouper** (*Epinephelus aeneus*)
Kalymnos	**Mediterranean shore crab** (*Carcinus aestuarii*) **Atlantic cod** (*Gadus morhua*) **European lobster** (*Homarus gamarus*) **European hake** (*Merluccius merlucius*) **Blue mussel** (*Mytilus edulis*) **Mediterranean mussel** (*Mytilus galloprovincialis*) **California king crab** (*Paralithodes californiensis*) **Giant tiger prawn** (*Penaeus monodon*) **Carramote prawn** (*Penaeus kerathurus*) **Mediterranean tellin clam** (*Peronaea planata*)	**European seabass*** *(Dicentrarchus labrax*) **Gilthead seabream*** (*Sparus aurata*)	**Purple sea urchin** (*Paracentrotus lividus*) **Goldblotch grouper** (*Epinephelus costae*) **Dusky grouper** *(Epinephelus marginatus)* **White grouper** (*Epinephelus aeneus*)
Pserimos	**-**	**European seabass*** *(Dicentrarchus labrax*) **Gilthead seabream*** (*Sparus aurata*)	**-**
Telendos	**-**	**European seabass*** *(Dicentrarchus labrax*) **Gilthead seabream*** (*Sparus aurata*)	**-**

8.5.2 Product Availability - Choice Task

Region of Origin

Of the 153 species recorded by Market Survey, 90 (58.8%) originate in The Mediterranean and Black Sea, 60 (39.2%) originate from outside this region (i.e. the rest of the world) and just three (2.0%); the Common Octopus (*Octopus vulgaris*), the Atlantic bonito (*Sarda sarda*) and the European Pilchard (*Sardina pilchardus*), are species that are extracted from both (Figure 165). These three species were recorded in the geographically adjacent West African (FAO Region 34) and North Atlantic (FAO Region 27) fisheries.

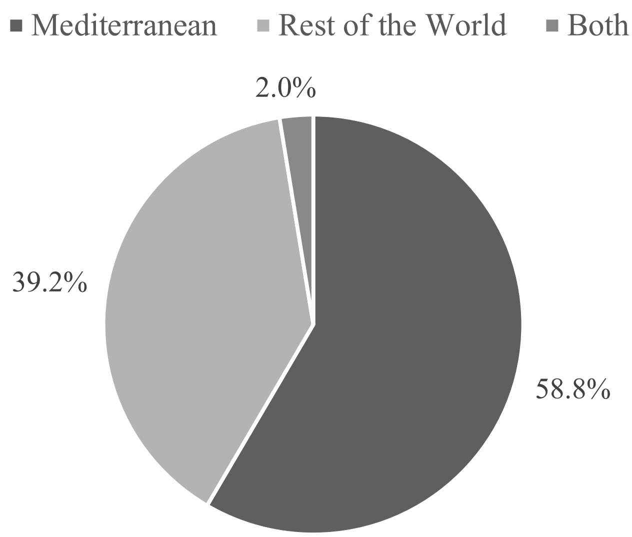

Figure 140. Place of origin for marine seafood products identified by Market Survey.

The 2.6% of species that are found in *both* the Mediterranean Sea and elsewhere are the European pilchard (*Sardina pilchardus*) (originating from fisheries of the countries of Morocco, Portugal and Denmark), the globally distributed Common octopus (*Octopus vulgaris*) (imported from Thailand) and the high economic value (€25/kg) White grouper (*Epinephelus aeneus*), and Surmullet (€20/kg) from proximal West African waters.

Within the 'Mediterranean Origin' data, there are several species of invasive fish

(Lessepsian migrants) that are novel and important additions to the local seafood supply chain. These include the Dusky spinefoot (*Siganus luridus*), Marbled spinefoot (*Siganus rivulatus*) and the Redcoat (*Sargocentrum rubrum)*. To further complicate the picture, the aquaculture industry is also bringing novel species into the Mediterranean seafood supply chains including locally (Leros) farmed species of Japanese seabream (*Pagrus major*) and the Rainbow trout (*Oncorrynchus mykiss*) which is farmed both in freshwater in Greece and in the Black Sea (Akbulut, 2002).

Ocean of Origin

Seafood products were recorded in the northern Dodecanese archipelago from every major fishing area outside of the Arctic (Major Fishing Area 18) and the Antarctic (Major Fishing Areas 48, 58, and 88) illustrating the truly global nature of seafood supply chains (Figure 166). The vast majority of species (n=90) traced their origin to the Mediterranean and Black Sea (Major Fishing Area 37). The greatest external contribution was from the 'Indian Ocean, Eastern' (Major Fishing Area 57) which contributed 22 species (Figure 166).

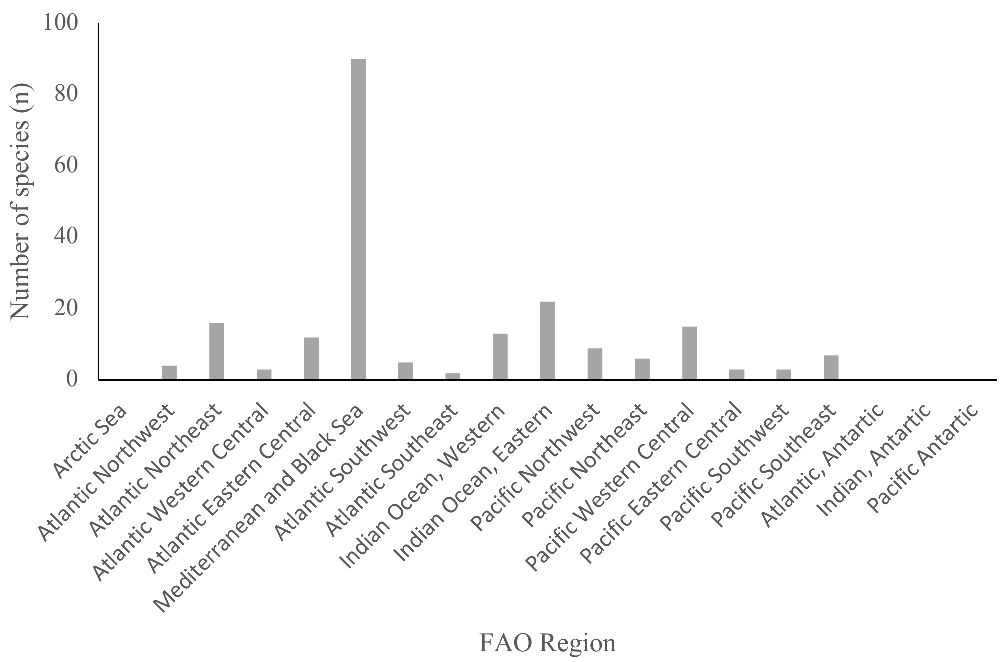

Figure 141. **Seafood product richness (species) recorded by Market Survey presented as originating from each of the Food and Agricultural Organisations (FAO) Major Fishing Areas.**

Seafood products are imported from the Pacific, Atlantic and Indian Ocean basins. The Pacific Ocean contributed the greatest diversity of seafood products (33 species, 16 families) followed by the Atlantic Ocean (31 species, 17 families) and finally the Indian Ocean (20 species, 8 families). The mean species richness originating from Major Fishing Areas in each of these three oceans is presented in Figure 167. Mean seafood product (species) richness was highest from the Indian Ocean 7.5 (±4.5), second highest from the Atlantic Ocean 6.8 (±2.2) and lowest from the Pacific Ocean 6.5 (±1.8). The total number of families and species imported from each of the three oceans are also presented in Figure 167.

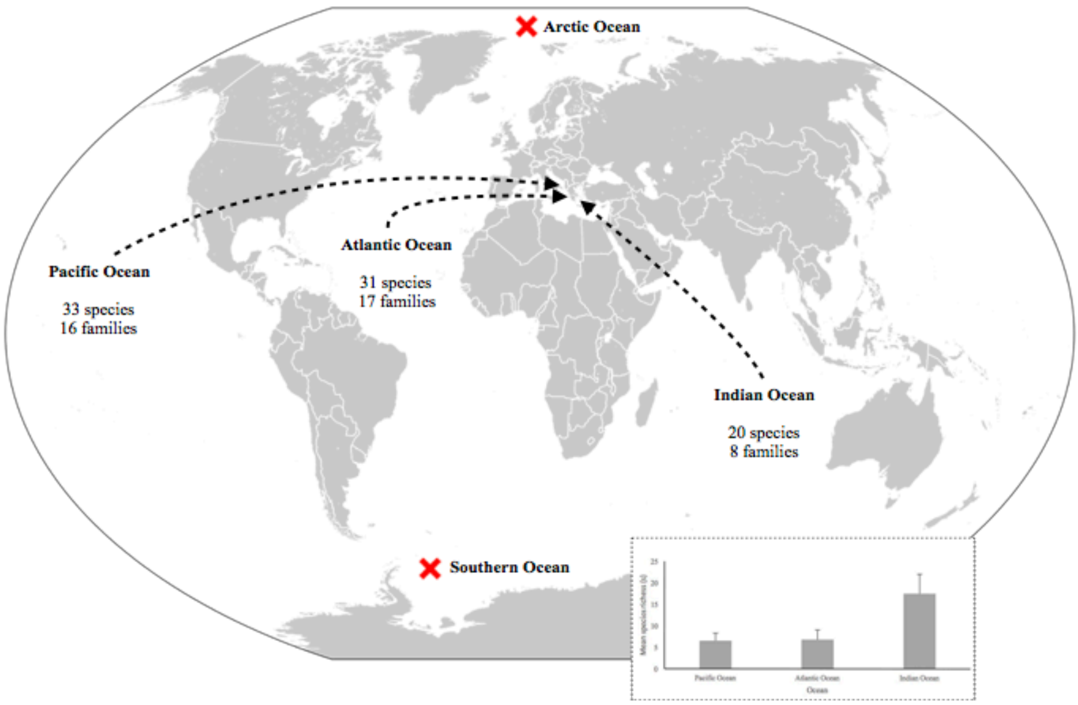

Figure 142. Oceans contributing to seafood product supply in the northern Dodecanese, including a graph illustrating mean (±SE) seafood product (species) richness originating from each of the three oceans.

The specific seafood product contribution to the supply chain varied between each ocean. These species are presented in Table 58.

Table 45. Imported seafood product contribution to the northern Dodecanse seafood supply chain. Presented as originating from each of the world's major oceans.

Ocean	Family	Species
Atlantic Ocean	Clupeidae	*Clupea harengus*
	Clupeidae	*Sardina pilchardus*
	Clupeidae	*Sprattus sprattus*
	Gadidae	*Gadus morhua*
	Gadidae	*Melanogrammus aeglefinus*
	Loliginidae	*Loligo gahi*
	Merluccidae	*Merluccius hubbsi*
	Merluccidae	*Merluccius merluccius*
	Mullidae	*Pseudupeneus prayensis*
	Mytilidae	*Mytilus edulis*
	Nephropidae	*Homarus americanus*
	Nephropidae	*Homarus gamarus*
	Octopodidae	*Octopus vulgaris*
	Ommastrephidae	*Illex argentinus*
	Pectinidae	*Pecten maximus*
	Penaeidae	*Penaeus notialis*
	Penaeidae	*Penaeus schmitti*
	Penaeidae	*Pleoticus muelleri*
	Pleuronectidae	*Pleuronectes platessa*
	Portunidae	*Callinectes sapidus*
	Salmonidae	*Salmo salar*
	Scombridae	*Katsuwonus pelamis*
	Scombridae	*Sarda sarda*
	Scombridae	*Scomber colias*
	Scombridae	*Scomber scombrus*
	Scombridae	*Thunnus alalunga*
	Scombridae	*Thunnus albacares*
	Scombridae	*Thunnus obesus*
	Sebastidae	*Sebastes marinus*
	Sebastidae	*Sebastes mentella*
	Serranidae	*Epinephelus aeneus*
Indian Ocean	Clupeidae	*Sardinella gibbosa*
	Loliginidae	*Uroteuthis duvaucelii*
	Mytilidae	*Perna viridis*
	Octopodidae	*Octopus vulgaris*
	Penaeidae	*Fenneropenaeus indicus*
	Penaeidae	*Litopenaeus vannamei*
	Penaeidae	*Metapenaeus affinis*
	Penaeidae	*Metapenaeus dobsoni*
	Penaeidae	*Metapenaeus monoceros*
	Penaeidae	*Metapeneopsis stridulans*
	Penaeidae	*Parapenaeopsis stylifera*
	Penaeidae	*Penaeus monodon*
	Penaeidae	*Penaeus semisulcatus*
	Portunidae	*Charybdis feriatus*
	Scombridae	*Katsuwonus pelamis*

	Scombridae	*Rastrelliger brachysoma*
	Scombridae	*Thunnus albacares*
	Scombridae	*Thunnus obesus*
	Scombridae	*Thunnus tonggol*
	Veneridae	*Paphia undulata*
Pacific Ocean	Anoplopomatidae	*Anoplopoma fimbria*
	Clupeidae	*Sardinella gibbosa*
	Gadidae	*Gadus chalcogrammus*
	Gadidae	*Gadus macrocephalus*
	Lithodidae	*Paralithodes californiensis*
	Loliginidae	*Doryteuthis opalescens*
	Loliginidae	*Uroteuthis duvaucelii*
	Mytilidae	*Mytilus chilensis*
	Mytilidae	*Perna canalicula*
	Mytilidae	*Perna viridis*
	Nemipteridae	*Nemipterus virgatus*
	Octopodidae	*Octopus vulgaris*
	Ommastrephidae	*Dosidicus gigas*
	Ommastrephidae	*Nototodarus sloanii*
	Ommastrephidae	*Todarodes pacificus*
	Penaeidae	*Litopenaeus vannamei*
	Penaeidae	*Metapeneopsis stridulans*
	Penaeidae	*Penaeus monodon*
	Pleuronectidae	*Limanda aspera*
	Portunidae	*Charybdis feriatus*
	Salmonidae	*Oncorhynchus gorbuscha*
	Salmonidae	*Oncorhynchus keta*
	Salmonidae	*Salmo salar*
	Scomberesocidae	*Cololabis adocetus*
	Scombridae	*Katsuwonus pelamis*
	Scombridae	*Rastrelliger brachysoma*
	Scombridae	*Sarda chiliensis*
	Scombridae	*Scomber australasicus*
	Scombridae	*Scomber scombrus*
	Scombridae	*Thunnus albacares*
	Scombridae	*Thunnus obesus*
	Scombridae	*Thunnus tonggol*
	Veneridae	*Paphia undulata*

The family Scombridae (Mackerels and Tunas) were the largest contributors (by species) from both the Atlantic Ocean (7 species) and Pacific Ocean (8 species) and second in the Indian Ocean (5 species). Penaeidae (Prawns) were the most diverse contributor from the Indian Ocean (9 species) but were also the second most diverse contributors from the Atlantic Ocean and Pacific Ocean. Together the Scombridae and Penaeidae accounted for 32%, 70% and 33% of the Atlantic, Indian and Pacific Ocean imports respectively.

The Atlantic Ocean had strong representation from the Clupeidae (Herrings and Sardines); 3 species (10% of Atlantic Ocean diversity) and the Pacific Ocean from the Salmonidae (Salmon); 3 species (9% of Pacific Ocean diversity), the Mytilidae (Mussels); 3 species (9% of Pacific Ocean diversity), and the Omnastrephidae (Arrow squids); 3 species and Loliginidae (Pencil squids); 2 species (a combined 15% of Pacific Ocean Diversity).

In addition, to this marine seafood product supply a few freshwater fish products are now also being traded internationally (Table 59).

Table 46. The FAO Major Fishing Areas (Inland) and associated seafood exports.

	FAO Major Fishing Area	Seafood products (Species)
01	Africa - Inland waters	Nile perch (*Lates niloticus*)
02	America, North - Inland waters	None recorded
03	America, South - Inland waters	None recorded
04	Asia - Inland waters	Iridescent shark (*Pangasius hypophthalmus*)
05	Europe - Inland waters	Rainbow trout (*Oncorrynchus mykiss*)
06	Oceania - Inland waters	None recorded
07	Former USSR area - Inland waters	None recorded
08	Antarctica - Inland waters	None recorded

Continent of Origin

Seafood products imported from 41 countries were recorded by Market Survey, with African (n=12) and European nations (n=10) the most numerous contributors to northern Dodecanese seafood supply (Table 60)

Table 47. A table illustrating the 41 countries from which Greece imports seafood product for sale in the northern Dodecanese. Top three exporters are labelled 1, 2 and 3.

North America	South America	Europe	Africa	Asia	Oceania
Canada	Argentina	Croatia	Angola	Bangladesh	Indonesia
Cuba	Chile	Denmark	Cape Verde	China	Kiribati

El Salvador	Ecuador	France	Gabon	India[3]	New Zealand
USA[2]	Perú	Germany	Ghana	Thailand[1]	Philippines
		Latvia	Guinea-Bissau	Vietnam	Tuvalu
		Norway	Ivory Coast		
		Portugal	Mauritius		
		Scotland	Morocco		
		Spain	Sao Tomé & Principe		
		Sweden	Senegal		
			Seychelles		
			Sierra Leone		

However, it was the nations of North America; 4.3 (±1.9) and Asia 4.6 (±2.2) that supplied the greatest variety of seafood products (Figure 168) with imports from European nations 1.3 (±0.3) often limited to just one species. For example, Atlantic Salmon (*Salmo salar*) from Scotland or Baltic Sea sprats (*Sprattus sprattus*) from Latvia. South America 1.8 (±0.5), Africa 2.3 (±0.3) and Oceania (2.3 ± 0.6) showed intermediate variety in products supply.

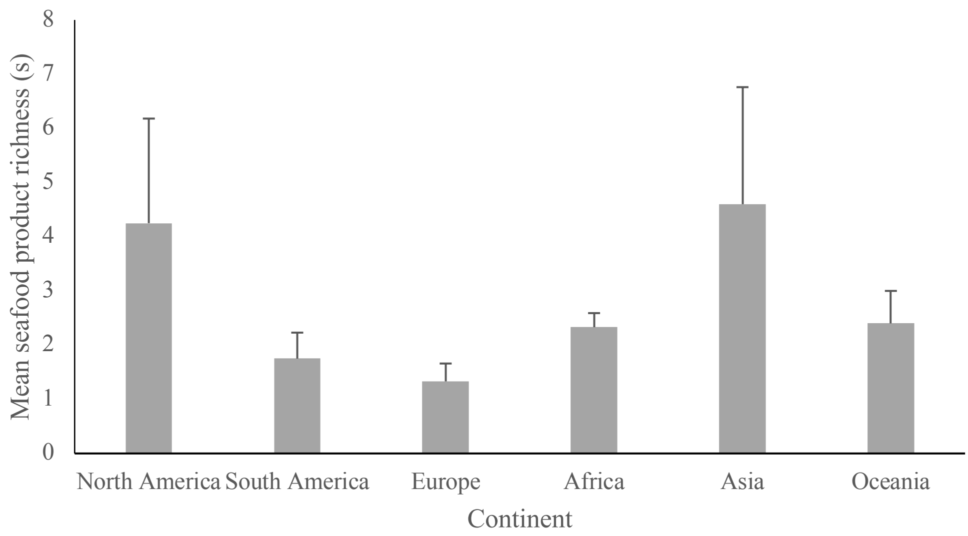

Figure 143. Mean (±SE) species richness (number of seafood products imported) to the northern Dodecanese archipelago (Market*place*) from each of the six continents.

Imported species ranged from locally available European pilchards (*Sardina pilchardus*) from nearby Croatia (supplementing domestic supply), to international products such as the greenshell mussels (*Perna canaliculi*), Southern pink and white shrimps (*Penaeus notialis / Penaeus schmitti)* or farmed Atlantic Salmon (*Salmo salar*) imported from distant New Zealand (FAO Region 81), Cuba (FAO Region 31) and Chile (FAO Region 87) respectively (Figure 144).

Figure 144. Countries of origin for the seafood products available in the northern Dodecanese, with seafood exporters highlighted in dark grey.

Within each continent, it can be seen (Figure 169) that clusters of countries in each region are often responsible for the exported produce. This is important information for Sustainable Supply Chain Management (SSCM) because should factors develop in these regions that threaten seafood supply, either socio-economic (e.g. conflict / war) or ecological e.g. stock collapse the concentration of seafood supply coming from a few nations means that local food security could be at stake if seafood supply is interrupted.

In Europe, the Atlantic Ocean facing nations provide species that are unavailable to domestic Greek fleets operating in the Mediterranean. In both South America and Africa, the countries along the west coast are where the seafood products available in the Dodecanese tend to originate. In Asia and Oceania, the waters surrounding the nations of sub-tropical and tropical coasts of south-east Asia form a cluster of seafood exporter nations. In all oceans, the export of tuna species (*Thunnus obesus,* *Thunnus albacares, Katsuwonus pelamis*) from small-island developing states (SIDS) is present; Cape Verde and Sao Tomé and Principle (Atlantic Ocean), Mauritus and Seychelles (Indian Ocean), Kiribati, Tokelau and Tuvalu (Pacific Ocean).

For SSCM, the import of tuna species from numerous Small Island Developing States (SIDS) spreads the supply chain risk across numerous providers. However, such dispersion of risk is not true for other products, for example, with Atlantic Salmon (*Salmo salar*) the risks of supply interruptions are concentrated amongst just a few, albeit traditionally more politically, socially and econimically stable (e.g. Norway, Scotland, Chile), nations.

Cluster analysis revealed differentiation in the species of seafood products supplied from each continent (Figure 170a). Here, *Europe* offered very low similarity with imported produce from other continents (just two species; Atlantic Salmon (*Salmo salar*) from *South America*, and the Atlantic Cod (*Gadus* morhua) from *North America*).

In comparison, all other continents exported seafood products that were more similar at the 20% level (Figure 170b). *Asia* was dissimilar at the 25% level and *Africa* at the 30% level. At the 35 % level, only *South America* and *Oceania* were exporting similar products. Across all continents similarities were largely driven by export of species of tuna (Scombridae), with Asia being most dissimilar due to the export of various prawn (Penaiedae) species.

With regards to SSCM this highlights the reliance on Asian seafood supply chains for the continuity of supply of the commercially important (see Chapter 8) prawn species. Here, the sustainability of imported supply, and the 'reliance’ on imported species within the Greek tourist sector, is therefore a reliance on the sustainability of fisheries in Asian region – risk factors that are outside the direct control of local supply chain managers.

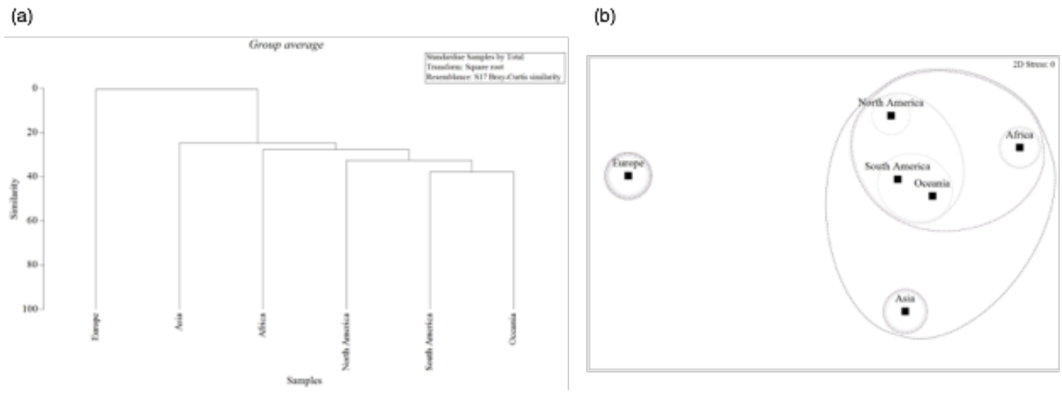

Figure 145. (a) Cluster analysis (b) nMDS ordination showing the similarities of seafood products available to consumers from each of the six continents.

The specific species that are imported from each region are reported to highlight for Sustainable Supply Chain Managent (SSCM) the seafood products that could be at risk if there was disruption to seafood product supply from a particular geographical region:

North American seafood imports were characterized by 14 species of seafood. There were two imports from Canada, the American lobster (*Homarus americanus*) from the east coast and the Pink Salmon (*Oncorhynchus gorbuscha*) from the west coast. From Cuba two species of shrimp; southern pink shrimp (*Penaeus notialis*) and southern white shrimp (*Penaeus schmitti*) were imported and imports from El Salvador were characterized by three species of tuna fish: Bigeye (*Thunnus obesus*), Yellowfin (*Thunnus albacares*) and Skipjack (*Katsuwonus pelamis*). The most diverse exporter from the region was the USA. From the east coast the Chesapeake blue crab (*Callinectes* sapidus) was imported alongside the Atlantic cod (*Gadus morhua*), Haddock (*Melanogrammus aeglefinus*) and Plaice (*Pleuronectes platessa*). From the west coast the Alaska Pollock (*Gadus chalcogrammus*) and Yellowfin sole (*Limanda aspera*) were imported alongside two species of salmon; Chum salmon (*Oncorhynchus keta*) and Pink salmon (*Oncorhynchus gorbuscha*).

South American seafood imports were characterized by 6 species. These were limited to the Argentine red shrimp (*Pleoticus muelleri*) from Argentina and the Chilean blue mussel (*Myilus chilensis*) from Chile. Farmed Atlantic salmon (*Salmo salar*) was also imported from Chilian waters. Skipjack tuna (*Katsuwonus pelamis*) was imported from both Ecuador and Peru, with Yellowfin tuna (*Thunnus albacares*) and Bigeye tuna (*Thunnus obesus*) also being exported from Peru.

European imports were also characterized by 6 species. From Denmark, Croatia and Portugal came European pilchard (*Sardina pilchardus*); and from Denmark, Germany and France the Atlantic herring (*Clupea harengus*). The European sprat (*Sprattus sprattus*) was imported from Latvia and the Atlantic mackerel from Denmark. Farmed seafood products were also imported from Europe, comprising the European blue mussel (*Myilus edulis*) from Denmark and Sweden and the Atlantic salmon (*Salmo salar*) from Scotland and Norway.

African imports were characterized by 6 species. European pilchard (*Sardina pilchardus*) was imported from Morocco along with Southern pink shrimp (*Penaeus notialis*). The remaining seven west African nations were characterized by three species of tuna fish; Bigeye (*Thunnus obesus*), Yellowfin (*Thunnus albacares*) and Skipjack (*Katsuwonus pelamis*). The only exceptions being Ghana from which imports were only Yellowfin (*Thunnus albacares*) and Skipjack tuna (*Katsuwonus pelamis*). From the East African island groups of the Seychelles and Mauritius Yellowfin (*Thunnus albacares*) and Skipjack tuna (*Katsuwonus pelamis*), and just Yellowfin tuna (*Thunnus albacares*) were imported respectively.

Asian imports were characterized by 15 species. From Bangladesh, China, India and Vietnam the Giant tiger prawn (*Penaeus monodon*) from Vietnam and Thailand, the Skipjack (*Katsuwonus pelamis*) and Yellowfin tuna (*Thunnus albacares*) were imported. From India, imports included Kiddi (*Parapenaeopsis stylifera*), Kadal (*Metapenaeus dobsoni*), Jinga (*Metapenaeus* affinis), and Speckled (*Metapenaeus monoceros*) shrimp and the Green tiger prawn (*Penaeus semisulcatus*) and the Indian prawn (*Fenneropenaeus indicus*). From Thailand imports included the Whiteleg (*Litopenaus vannamei*) and Fiddler (*Metapenaeopsis stridulans*) shrimps, the Indian squid (*Uroteuthis duvaucelli*) the Crucifix crab (*Charybdis feriatus*) the Asian green mussel (*Perna viridis*) the undulated surf clam (*Paphia undulata*), the common Octopus (*Octopus vulgaris*) the Goldstripe sardinella (*Sardinella gibbosa*) and the Short mackerel (*Rastrelliger brachysoma*)

Oceania imports were characterized by just five species. These included the Giant tiger prawn (*Penaeus monodon*) from Indonesia and the Greenshell mussel (*Perna canaliculi*) from New Zealand. The remaining species are three species of tuna fish; Bigeye (*Thunnus obesus*), Yellowfin (*Thunnus albacares*) and Skipjack (*Katsuwonus pelamis*) imported from Kiribati, Tuvalu and Tokelau (territory of New Zealand). Skipjack tuna was the only species imported from the Phillipines (*Katsuwonus pelamis*).

Species which could be identified, but not traced to a particular nation include the Redfish (*Sebastes marinus*), the Rosefish (*Sebastes mentella*), the Golden threadfin bream (*Nemipterus virgatus*) the Black sea sprat (*Clupeonella cultriventris*) the Pacific mackerel (*Scomber australasicus*), the California king crab (*Paralithodes californiensis,)* the Humboldt squid (*Dosidicus gigas*), the West African goatfish (*Pseudupeneus prayensis*), the Pacific cod (*Gadus microcephalus*) the King Scallop (*Pecten maximus*), the Musky octopus (*Eledone moschata*), the Argentine hake (*Merluccius hubbsi*), the New Zealand arrow squid (*Nototodarus sloanii*), the Japanese flying squid (*Todarodes pacificus*) the Patagonian squid (*Loligo gahi*) and the Argentine shortfin squid (*Illex argentines*). Although each of these species is known to come from a particular region.

Species that occurred globally (were imported from every region except Europe) were three species of tuna fish; the Skipjack (*Katsuwonus pelamis*), Yellowfin (*Thunnus albacares*) and Bigeye (*Thunnus obesus*).

8.5.3 Product Presentation (Choice Options)

Food presentation, and in particular food packaging has been found to be a strong driver for consumers' food choices (Mueller Loose et al., 2013), and packaging characteristics have been observed to demand significant market price differences (Mueller Loose & Szolnoki, 2012). Packaging presentation not only triggers consumers' subconscious symbolic associations and valuations (Becker et al., 2011) but also affects consumers' ability to inspect food characteristics and to transport the product safely (Mueller Loose et al., 2013). For these reasons (and of concern to the SSCF conceptual framework) the demand by consumers for the specific presentation of a given seafood product may be higher than the demand for other seafood products. For Supply Chain Managers, this knowledge is essential since it can help explain the demand for particular seafood products that are either imported or originate in the Lipsi Small-Scale Capture Fishery.

Market Survey data revealed mean seafood product (species) richness to be highest across the islands as *fresh* fish 69.0 (±0.0). However, *tinned* products offered the second highest level of choice with 11.4 (±4.0) seafood species available to consumers followed by *frozen* products offering 8.0 (±1.5) species (Figure 171). The lowest species richness *came from refrigerated* products which comprised either seafood products of European origin e.g. European lobster (*Homarus gammarus*), European anchovy (*Engraulis encrasicolus*), European pilchard (*Sardina* pilchardus) or otherwise preserved products for international imports e.g. filtered smoked as in the case of Yellowfin Tuna steaks (see Pivarnik et al, 2011).

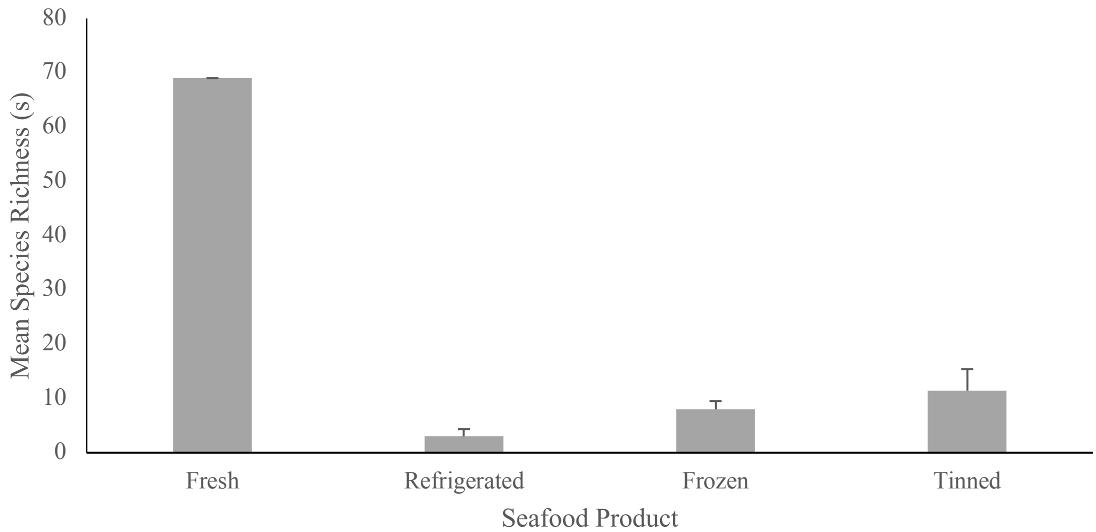

Figure 146. Mean (±SE) species richness by product type across islands where they were found; fresh, refrigerated, frozen and tinned.

Twelve species were available in *refrigerated* format whilst 31 species were available in *tinned* format. 43 species were available in frozen format and a further 11 families were available as frozen products which had not been identified to species level. These were miscellaneous species of Anchovy (Engraulidae), Flying and shortfin squid (Ommastrephidae), Right-eye flounders (Pleuronectidae), Pencil squids (Loliginidae), Bivavle mussels (Mytilidae), Threadfin breams (Nemipteridae), Lobsters (Nephropidae), Octopus (Octopodidae), Prawns (Penaeidae), Herrings and Sardines (Clupeidae) and Cuttlefish (Sepiidae).

Cluster analysis showed differentiation between species presented in seafood products (Figure 172a). Here the small-scale capture fishery offered *fresh* seafood species which were dissimilar to those available in *frozen, tinned or refrigerated* forms. *Refrigerated* products were similar to *tinned* products at the 25% level (Figure 172b). Those species that were available in both refrigerated and tinned formats were the Atlantic herring (*Clupea harengus*), European anchovy (*Engraulis encrasicolus*), European pilchard (*Sardina* pilchardus), the Common octopus (*Octopus vulgaris*), the Atlantic salmon (*Salmo salar*), the Atlantic mackerel (*Scomber scombrus*) and the Chub mackerel (*Scomber colias*).

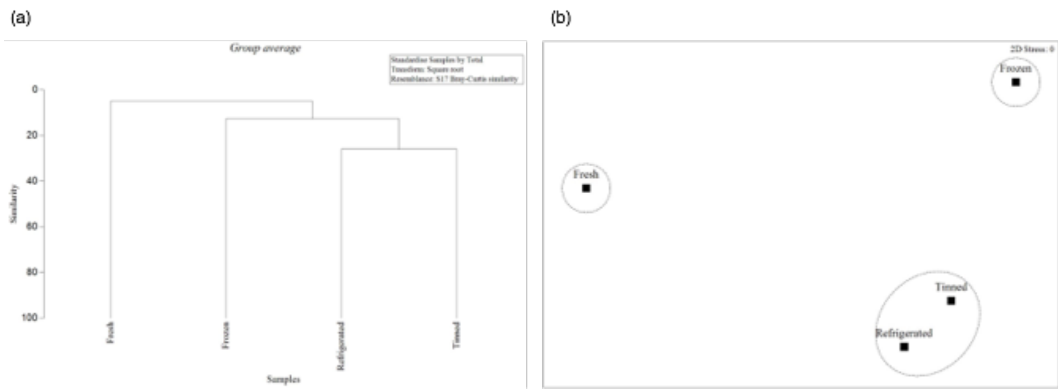

Figure 147. (a) Cluster analysis (b) nMDS ordination showing the similarities of seafood product types available to consumers.

For some seafood species there were often several brands than marketed the same product, from the same regions, but in a variety of different ways. For example;

1. Atlantic herring (*Clupea harengus*) from Major Fishing Area 27: For *refrigerated* Atlantic herring (*Clupea harengus*) consumers could buy either 800g of “Kalloni” branded herring of unspecified origin, or 100g of “Les supérieurs” branded product

from France. However, they could also buy 100g or 200g *tins of* Atlantic herring from the Danish "Petri" brand or 200g tins from the German brands "Rügenfisch" and "Niko".

2. Atlantic salmon (*Salmo salar*) from Major Fishing Area 27 & 87: For *refrigerated* Atlantic salmon (*Salmo salar*) consumers could buy 100g, vacuum-packed, Vassilopoulous own-brand (AB Supermarket) product from Scotland/Norway or 200g of a "John Ross", vacuum-packed, branded product from Scotland. On Patmos, they could also be presented with premium 'deli-style' "Scottish Salmon" for €51.90/kg should they be willing to pay for it. Consumers could also purchase 160g of *tinned* "Rio Mar" Atlantic salmon from Chile & Norway or 750g of *frozen* Norwegian Atlantic salmon.

In contrast, for other seafood species the product type was always the same e.g. only *frozen* or only *tinned* but the supplier and country of origin varied. For example

1. Giant tiger prawn (*Penaeus monodon*) from Major Fishing Areas 51, 57, 61, 71 were available in boxed and frozen form, from 500g to 2000g, from Mers du Monde from Indonesia, Price Brand, Bright Brand and Rosemco from Bangladesh, Castlerock from India, Ben's Easy Kitchen from Vietnam and 7ΘΑΛΑΣΣΕΣ from China

2. Yellowfin tuna (*Thunnus albacares*) from Major Fishing Areas 34, 51, 71: only available in 160g *tinned* form. This was imported from Mauritius under the "Rio Mar" brand, from "ΕΛΟΜΑΣ Quality Line" from Ghana and from "Neptuna" or "Alta gusto" from Thailand

Results show that consumers are regularly being presented with a multitude of different choice options for the same species i.e. size / condition / origin / branding which is likely to have an impact on consumer decision making and patterns of consumption. Such factors are also likely to directly affect the demand for particular product types and therefore the pressure on local SSCF fleets to deliver particular product types to the marketplace. Previous studies have identified perceived inconvenience (amongst several other factors) as a substantial barrier to seafood consumption (e.g. Altintzoglou et al., 2010; Olsen et al., 2007; Rortveit and Olsen, 2009). In these studies the consumers have either believed seafood preparation to be too time consuming, or they have felt they lack the knowledge for seafood preparation. Consumers have also cited that they are often inexperienced in judging the freshness of seafood products (e.g. Pieniak et al., 2007) and therefore are reluctant to purchase 'fresh' produce.

Figure 148 - A tuna for sale at a fishmonger in the town of Lakki, Leros. Most tuna is imported but some is still caught in the Aegean Sea.

However, are these studies are unlikely to be reflective of the average consumer from a traditional small Greek island fishing community? Such barriers could potentially be overcome by smart retailing and packaging solutions making transport, preparation and storage easier for customers, but their relative importance and impact on market share are so far largely unknown (Mueller Loose et al., 2013)

8.6 Discussion

The way choice is presented influences what decision-makers (i.e. consumers) choose (Johnson et al. 2012). Therefore, in the context of the perceived sustainability of "Habitat to Consumer" seafood product supply chain, it is important to understand which products (species) and from which suppliers (habitats) are being presented to consumers in the marketplace. In addition, it is also important to understand *how* these products are being presented. Interrogation of the Marketplace is essential in understanding the socio-economic context in which the SSCF supply chain finds itself; is the supply chain in competition with other seafood supply chains, or is it being supplemented by them? Are seafood products being actively promoted from elsewhere? Or is Lipsi SSCF seafood supply-chain solely responsible for island seafood security?

In this Chapter the ‘Marketplace’ was considered at the scale of the northern Dodecanese (specifically those islands within a 60-minute journey from Lipsi) and it was interrogated to elicit an understanding of the ‘choice’ presented to seafood consumers, and therefore the ‘choice architecture’ (sensu Thaler and Sunstein 2008) of the defined market ‘place’.

The choice architecture was divided into three categories; those that were used in the enabling the ‘choice capacity’, those that were used in structuring the ‘choice task’ and those that were used in describing the ‘choice options’. The three of these elements being hierarchical: For example, a supermarket may enable the importation of mussels (Mytilidae) through established supply chains (Choice Capacity). The supermarket may have access to three mussel supply chains, but decide to stock Chilean mussels (*Mytilus chilensis*) and Atlantic blue mussels (*Mytilus edulis*) instead of native *Mytilus galloprovincialis*) (Choice Task). Finally, the Chilean mussels might be presented in a frozen format, whilst the Atlantic mussels are presented in a tinned format (Choice Options). In this example, the retailer attributes that enabled the Choice Capacity addressed the question of what products it is possible to present to decision makers based upon the existence or absence of seafood supply chains. This was analysed via consideration of ‘Retailer Type’, with the rational being that different retailers would have differential access to seafood supply chains, and therefore the Choice Capacity would vary between islands depending upon retailer presence/absence. Tools for structuring the Choice Task address the idea of what to present to decision-makers, here the variety of species being presented was analysed to understand the range offered to consumers.

Finally, through describing the Choice Options, this chapter addressed the choice-architecture idea of how to present products. This was explored via the product packaging, for example whether a species was presented as fresh, or whether it had been packaged and refrigerated, frozen or tinned for longer term storage.

The presence of large supermarkets in the northern Dodecanese appears to have structured the capacity for choice by enabling access to international seafood supply chains and therefore a whole suite of imported products. In contrast, those (smaller) islands without a formalised retail sector (Mini/Metro/Super-Market) were limited to species the local fishery could supply. This finding, although expected, confirms that for the Sustainable Supply Chain Management (SSCM) of the Lipsi Small-Scale Capture Fishery (SSCF) the Marketplace ‘context’ has evolved over recent decades and is continuing to do so. In particular, transport infrastructure modernisation and the ‘supermarketisation’ of retailing is changing the context, and thus the ‘goalposts’ for fishery sustainability, specifically the capacity for consumers on Lipsi to consume seafood products (either by choice or necessity) not originating from the SSCF.

Understanding the patterns and trends of product availability in any given place is important for SSCM since seafood consumers will make informed decisions of product purchase based upon the choice task presented to them i.e. does a consumer purchase the Chub mackerel (*Scomber japonicas*) from one of the fishers of Lipsi SSCF? Or does the consumer purchase the Pacific mackerel (*Scomber australasicus*) if presented with both options. Choice options and other socio-economic factors aside, such a choice task is only ever present where the retailer has chosen to present both seafood products. On the small islands without access to imported fish, the only option is seafood products originating from the SSCF.

With enhanced Choice Capacity, consumers on Lipsi now have access to at least 153 species from 59 families imported from all regions of the oceans except the Arctic and Antarctic. Within these 153 species are seven that are amongst the top 10 species by capture production globally, and form a major component of internationally traded seafood products (FAO, 2014). These are Alaska Pollock (*Gadus chalcogramma*), the Skipjack tuna (*Katsuwonus pelamis*), the Chub mackerel (*Scomber* japonicas), the Atlantic herring (*Clupea harengus*), the Yellowfin tuna (*Thunnus albacares*), the Atlantic mackerel (*Scomber scombrus*) and the Atlantic cod (*Gadus morhua*). Within the top 76 species (those with capture production of 150,000 tonnes or more) a further 21 were presented as choice options to Lipsi consumers.

The marketplace trend is for more, not fewer, options for consumers (Johnson et al., 2012), complicating the decision-making process by offering numerous alternatives to existing products (Iyengar and Lepper, 2000; Schwartz, 2004). For example, imported individuals of a popular Mediterranean seafood species, the Surmullet (*Mullus surmuletus*) were being sold in a Super-Market on Patmos, alongside species of similar physical appearance; the West African goatfish (*Pseudupeneus prayensis)*. This illustrates there is a demand for particular 'types' of seafood products but that such demand may not currently be able to be fulfilled by domestic supply (see Zeller and Pauly, 2016).

The final element of the decision-making process also relates to how the product is presented, which itself may represent a trade-off between transport distance, transport time and transport cost. Indeed, some elements of consumer choice will be contingent upon the characteristics of the individual consumer, for example are they are local or a tourist, and do they thus have differing seafood preferences? Or do certain demographics make 'green choices' in their consumption patterns? Research suggests that older adults (with a lower processing capacity) prefer less choice than younger adults (Reed et al., 2008) and thus the Choice Task is more complicated than simply considering what a product looks like. However, within the context of this thesis, the packaging of the species was utilised as a proxy for Choice Task.

Despite an enhanced Choice Capacity, resulting in a greater variety of options available to consumers on Lipsi, there has been a proliferation in the variety of channels through which seafood products can be purchased in the northern Dodecanese. Seafood products are now sold 'fresh', 'frozen', 'refrigerated' or 'tinned' and in a suite of different stages of processing. This development of in product presentation, reflects reports from elsewhere in Greece. For example, Stamatis et al. (2005), reported a 'remarkable' increase of 250% in quantities of frozen seafood, and a slight increase of 9% in quantities of processed seafood in

Greece over the preceding decade. A pattern that, along with the 'supermaketistaion' of the Greek retail sector, can be expected to have continued.

Within the Mediterranean, significant regional differences in consumption trends exist, relating to quantities consumed, species preference, 'type' of products consumed, the 'quality' of labels, and the product availability and distribution (large surface supermarkets vs. specialized shops) (Paquotte and Guillard, 1996).
In Greece specifically, Arvanitoyannis et al. (2004) showed that the majority of consumers claim to prefer whole (unprocessed) fish rather than fillets or other kinds of portioned fish. However, they highlighted that this pattern was very typical of older Greek consumers who also exhibited a high degree of knowledge and expertise in selecting and preparing fish, while younger and more inexpert consumers were more willing to consume processed fish. This generational disparity was also found in Portugal (Caroso et al., 2013) and France (Debucquet et al., 2012).

8.6.1 Relevance to Small Scale Capture Fishery Sustainable Supply Chain Management

So, what is the relevance of these findings to Small Scale Capture Fishery Sustainable Supply Chain Management? Primarily the relevance is that currently management initiatives are being proposed against the backdrop of a rapidly evolving marketplace, with no clear trajectory towards 'unprocessed local' or 'processed global' produce.

Supply chain managers in Greece may feel that they are supporting Greek and European fisheries management efforts by importing products from across the globe. Indeed, by substituting products and marketing new products they are could argue they are simultaneously enhancing consumer 'choice' whilst also reducing seafood demand on overfished domestic supply chains. However, there is evidence to suggest that many of the detrimental effects of global imports (e.g. overfishing / collapse of supply) is currently being masked to consumers in the developed world since catches from the overseas are effectively just offsetting the shortfalls in supply from catch in developed nations (Pauly et al, 2005), and that there will come a day when there is a shortfall in supply from these distant oceans too. A recent review by Carlucci et al. (2015) suggest that in the wider context of consumer purchasing behaviour towards seafood products that;

"most consumers seem to prefer wild fish rather than farmed, domestic fish rather than imported, fresh fish rather than frozen and whole fish rather than processed but these patterns appear to be in contrast with some desires broadly expressed by the same consumers in terms of convenience, availability, low price and environment safeguard."

With regard to the conceptual framework proposed in Chapter 4, and the supply chain sustainability of the Lipsi Small-Scale Capture Fishery (SSCF) such contradictions present stark challenges to effective sustainable supply chain management. Such contradictions are evident in Australia, where Birch et al. (2012) found that most regular seafood consumers 'currently purchased' (64%) and 'preferred to purchase '(50%) unpackaged seafood products because they considered them to be less expensive and more guaranteed in terms of freshness and local origin.

However, the remaining participants appreciated mainly packaged fish products because of their greater convenience (selection from supermarket shelves without waiting to be served at the delicatessen section) and possibility of evaluating information such as assurance of freshness (use by date), country of origin, assurance of quality (branding) and more transparent pricing (price per portion).
In a 2004 Greek study, Arvanitoyannis et al. obtained broadly similar results, where 26% of younger respondents preferred to purchase packaged fish, citing their reasons for doing so as 'convenience' and 'safety'. What this suggests is seafood consumption patterns are evolving in response to lifestyle patterns present in younger consumers.

8.6.2 Management Recommendations

The development of international supply-chains and the growth of internationally traded seafood in the northern Dodecanse, can, in some respects, be beneficial. For example, it contributes towards removing the risk to consumers on Lipsi of an over-reliance of locally sourced seafood products from stocks which are overfished (Tsikliras et al., 2012; Chapter 7). However, it is also developing a long-term supply chain risk with the growing concerns of the over-exploitation of developing countries' fisheries which are now replacing domestic over-exploitation to serve the developed world (Alder and Sumaila, 2004; Swartz et al., 2010a; Swartz et al, 2010b; Jaunky 2011), whilst simultaneously reducing the pressure on governments to better manage domestic stocks. Additionally, the development has also promoted immediate economic challenges to the small-scale fishers who are 'forced to compete with the export-orientated industrial fleets without much support from their governments' (Zeller and Pauly, 2016).

Regarding SSCM recommendations, Carlucci et al's (2015) study, the seafood product attributes that that were reported as most relevant in affecting consumers' choices were country of origin, production and preserving methods, product innovation, packaging and eco-labelling. In addition, existing literature suggests that consumers prefer alternative markets, if they have a personal relationship with the retailer, but believe supermarkets are more reliable than random informal retailers (Hoang and Nakayasu 2006; Figuié and Moustier 2009). For these reasons, the structuring of choice architecture which biases the consumption of *locally abundant* species would provide the optimum solution. For example, the active-marketing to tourists of the abundant Dusky spinefoot (*Siganus luridus*) which, whist popular in the Indo-Pacific, is little esteemed by European consumers. Such a market-based approach is already being pushed to manage the invasion of Lionfish (*Pterois volitans*) in Belize (see Chapman et al, 2016, "Working up an appetite for lionfish"). Adopting such an approach could be marketed as environmentally responsible and innovative. Although such schemes are not without their challenges.

Brecard et al. (2009) reports that the European Commission found that while 75% of

European consumers indicate a wiliness to pay a premium for environmentally responsible products, in practice, only 17% reported that they had made such purchases recently. The study cites a lack of reliable consumer information to be a key contributing factor to this phenomenon (Brecard et al. 2009). The issue of globalised seafood supply chains was recently highlighted by Pauly and Zeller's (2016) Nature Communications paper where they highlighted how the growing popularity of fish in countries with developed (or rapidly developing economies) is creating a demand for seafood products that cannot be met by the fish stocks in local waters (e.g. Greece). Therefore, these markets are increasingly supplied by fish imported from developing countries, or caught in waters of developing countries by distant water fleets.

However, at present a lack of consumer 'demand' in the supply chain for sustainable seafood, and a lack of trust, or just a lack of information presented for traceability, have been cited as hurdles for implementing market-based initiatives that support seafood supply chain sustainability. On Lipsi there is scope to support the Lipsi Small-Scale Capture Fishery by marketing the products utilising the knowledge gained from application of the conceptual framework, with information pertaining to both the seafood product's location of origin and its (if applicable) sustainable nature.

8.5.5 Limitations and Future Research

This data set only records the diversity of seafood products available in the marketplace and not the volume of products being presented to consumers. This risks giving a much broader picture of global seafood extraction, which might in reality only be focussed on just a few key species (e.g. Tuna and Salmon) sold in high volumes. Further research could pursue a quantitative assessment of just how many (or much/weight) of each species is being presented to the consumer in the marketplace to give a clearer picture of global rates of extraction.

In the 'developed' world, it is perhaps in response to an increasingly dynamic lifestyle, or perhaps in response to a greater appreciation of environmental degradation, that many consumers are requiring information of these elements to inform their consumption choices. Therefore, although most fish and seafood products are still sold as unbranded and unlabelled items, it could be interesting to investigate the impact of branding and other specific label information such as health and nutritional claims on consumer choices (Carlucci et al., 2015).

CHAPTER 9 - Supply Chain Stage 5 - Consumer

9.1 Introduction

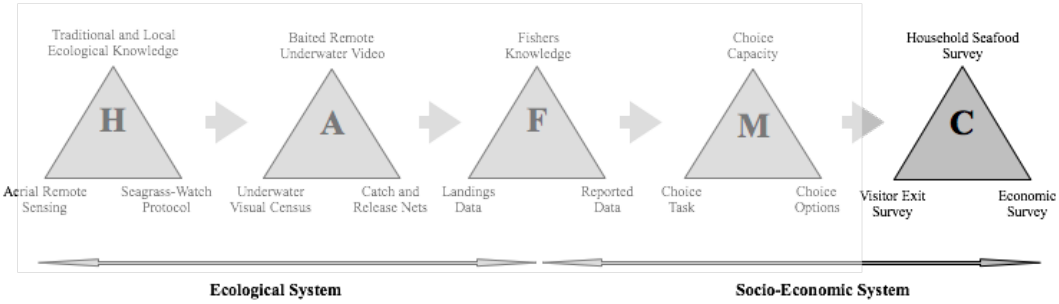

Figure 149. The Consumer (C) and the final stage of the Small-Scale Capture Fishery supply chain. This supply chain stage is located within what would be conventionally conceptualised as the socio-economic system.

The fifth and final stage in the 'Habitat to Consumer' Small-Scale Capture Fishery supply chain framework represents the 'final destination' for the seafood product; the consumer. It is at this final stage that the demand for seafood products is created. Whilst in many supply chains, there is much consumer influence on the social role of Market*place* (see Chapter 8), it is generally the needs (or desires) of the consumers themselves that will often have the greatest bearing on the type and volume of production supplied to Market.

However, under the Small-Scale Capture Fishery (SSCF) Sustainable Supply Chain Management (SSCM) conceptual framework this is not *necessarily* the case: In conventional supply chains, demand for products often stimulates production, but in natural resource based systems, production occurs irrespective of consumer demand.

This final stage of the SSCF supply chain framework offers the opportunity to explore the characteristics that influence the decisions taken by consumers in relation to their purchasing patterns. For example, do the seafood choices made by island residents differ from those of transient tourists? Is there a difference in the financial value assigned to seafood products on Lipsi? Is there likely a difference in purchasing power between social groups?

At this final stage in the 'Habitat to Consumer' supply chain framework, theories pertaining to 'consumer choice' play a key role. This is because 'choices' made are often influenced by the social, economic, and cultural context of place, in addition to the choice architecture elements explored in Chapter 8.

Specifically, this chapter explores socio-economic elements that may affect the decision-making process of consumers to favour one product over another which might be in part attributable to cultural traditions and social norms, or to discrepancies in purchasing power between different social groups.

In the proposed SSCF SSCM conceptual framework, exploring the context of seafood demand by different social groups, and exploring the potential for strong seasonality in demand for certain species, could do much to contextualise the demands made on the Lipsi SSCF supply chain by the tourist industry (which is significant in summer months and can easily double the number of people living on the island). Such pressure to meet demand could therefore change the behaviour and opinions of stakeholders in the fishery, especially when it comes to targeting specific species and / or habitats for extraction.

Consumer behaviour

Within the conceptual framework presented, it is conjectured that the actions of consumers underpin the market demand for seafood products, since it is these choices that individuals, and groups of consumers take, that create the 'demand' for seafood products in the supply chain. Consumer behaviour is thus considered in this thesis as the internal decision-making process by consumers about what seafood products to consume when presented with the choice architecture (sensu Thaler and Surstein, 2008) that was explored in the Chapter 8.

Consumer behaviour has recently been described as *'a fascinating but difficult subject to research'* (Horner and Swarbrooke, 2016) since so many elements (biological, psychological, socio-economic etc) influence consumer choice at any given moment. It has been defined as the study of *'why people buy what they do, and how they make their decision'* (Horner and Swarbrooke, 1996). The consumer behaviour process involves those activities that are *'directly involved in obtaining, consuming, and disposing of products and services including the decision processes that precedes and follows these actions'* (Blackwell et al., 2001). This definition places emphasises the psychological processes which the consumer goes through during the pre-purchase and post-purchase stages.

Solomon (2014) incorporates this psychological element of consumer 'needs' and 'wants' into his definition *'Consumer behaviour is the process involved when individuals or groups select, purchase, use, or dispose of products, services, ideas or experiences that satisfy needs and wants'.* This definition introduces the idea that consumer may make purchase decisions in groups, and not simply as individuals (Horner and Swarbrooke, 2016).

Two meta-analyses have suggested that 'green consumer' behaviour is a mixture of rational and moral decision making (Bamberg and Moser, 2007; Klockner, 2013) with attitudes and personal 'norms' being expressed as internalised social norms (Thøgersen 2009; Thøgersen 2014). For this reason, the social norms or 'tourists' from various international origins could be reasonable expected to have different social norms to residents of place. Consumer behaviours are considered here in the broader context of social groups, and therefore the broad patterns of seafood demand generated in the Small-Scale Capture Fishery supply chain by those that are considered 'tourists' of place and those that are considered 'residents' of place.

Hospitality and Tourism

In a developed retail sector, the pressure on retailers to meet consumer expectations and treat them 'well' are mounting, with an increased capacity for instant consumer reviews of retailers to be shared online. For example, there is increasing pressure on tourist restaurants (Figure 174) in Greece to meet consumer expectations and to outperform competitors in TripAdvisor rankings.

Figure 150. A popular tourist restaurant on Lipsi with great 'hospitality'. 'Hospitality' for tourists is not just about providing food and water but about the 'quality' of service given and the environment created, essentially the time and effort taken to 'look after guests well'.

TripAdvisor has become one of the world's largest travel websites; based on data from the company for the period April-June 2015, the website offers 250 million reviews and receives some 375 million visits per month. In addition, it has been found that consumers generally believe what they read on the site and make use of it when making purchasing decisions (Horner and Swarbrooke, 2016). Academic work has also generally validated the reliability of the reviews published on TripAdvisor (Tuominen, 2011; Ayeh et al., 2013; Chua and Banerjee, 2013)

The fierce competition for 'rankings' and 'reputation' could therefore be a central driving factor for retailers to move towards a standardisation of seafood product types that meets the expectations of the majority of tourists. Standardization or McDonaldization (Ritzer, 1998) is a powerful force in the restaurant industry because of its efficiency, calculability, and predictability of dishes and services (Erkuş-Öztürk and Terhorst, 2016). The latter reduces quality uncertainty which is a precondition for a well-functioning market (Beckert, 2009). Mass-tourism could well be seen as sharing similar attributes to the process of supermarketisation identified in the previous chapter;

"a process that stands for mass consumption, absence of class and life-style distinction, economies of scale, standardization, efficiency, predictability of quality, low prices, the transformation of authentic tourism places into standardized 'non-places', and disenchantment of consumption"

Erkus-Öztürk and Terhorst, 2016.

That said, the concept of mass-tourism is not without its criticisms, since the 'mass' of mass-tourism is actually made up of a large number of heterogeneous tourists from different backgrounds and cultures (for a critical discussion of mass tourism, see Singh, 2007; Vainikka, 2013). On Lipsi, mass-tourism is expressed both by domestic visitors as well as international and so it is highly likely that the tourists are heterogeneous with respect to food preferences, and therefore their seafood supply chain demands, because they come from different countries with different food cultures.

Competition and Innovation

For many retailers, moves are being made towards escaping the *'cut-throat price competition that goes with standardization'* (Erkus-Öztürk and Terhorst, 2016). This has resulted in innovation amongst retailers seeking to differentiate themselves through novel seafood product offerings and retailer experiences.

The idea of 'culinary innovation' has been the focus for several studies (e.g. Ottenbacher and Harrington 2009) although innovations in service and ambiance have also received attention (Rahman, 2010) as they are they are constituent parts of the consumer experience. In this context, although the seafood products themselves can't really be an innovative factor (the Small-Scale Capture Fishery seafood products landed at port are the same species for everyone), other elements such as retailer locations, their ambience, or their organisational structure may be.

According to the sociologist Bourdieu (1986), a large amount of economic, cultural, social, and symbolic capital help actors innovate in fields of cultural production. Recent 'innovations' however can be seen through the revisiting of 'traditional' and culturally important seafood products but deliberately differentiated to appeal to 'special interest tourists' from the 'food tourist' and 'cultural tourist' sectors (Horner and Swarbrooke, 2016).

Culture and tradition

There is a developing recognition of the role that 'food tourism' (Figure 175) has in sustaining regional identities (Everett and Aitchison, 2008) and it is accepted that food is an inextricable element of the touristic experience (Hall et al., 2003);

something that should not be surprising since all tourist must eat and food service is a core element of hospitality (Hall and Gössling, 2016). Food can act as a primary trip motivator (Quan and Wang, 2004) and it is in the inter-relationships between food, place and identity that food tourism's social and cultural impact is explored (Erkus-Öztürk and Terhorst, 2016). It must be acknowledged that:

'gastronomy has become a significant source of identity formation in post-modern societies'

Richards, 2002

Figure 151. Taste trekkers is a website catering speecifically to people who want to travel for the explicit purpose of tasting new local foods.

Correlations exist between increased levels of food tourism and the retention and development of regional identities (Everett and Aitchison, 2008), with such studies reflecting a need to better understand the increase in 'special interest tourism' as the sectors develop (Douglas et al., 2001). These developments have not occurred in isolation, and can be understood in relation to two main factors: first, concerns about economic and employment losses in many destinations, especially in developing countries with respect to the impact of food importation for tourists (Telfer and Wall, 1996); and second, the restructuring of economies in developed countries (as has occurred in Greece) as a result of globalization, technological change and prevailing neoliberal governance (Marsden et al, 1996; Hall and Gössling, 2016).

The potential role for such tourism as an 'instrument of regeneration' in remote regions has meant that certain types of special interest tourism are attracting interest within government policies, destination marketing strategies and travel media coverage (Everett and Aitchison, 2008). For supply chain managers, a better understanding the role potential capacity for manipulating demand for specific seafood products (towards a sustainable trajectory) could be central to effective Sustainable Supply Chain Management (SSCM) of the Lipsi Small-Scale Capture Fishery (SSCF).

Key to the food tourism concept is that often food tourism can be associated with *'the desire to experience a particular type of food or the produce of a specific region…'* (Hall et al., 2003) (e.g. local seafood products from the local place). This is in line with the idea of the rise of an 'experience economy' whereby value is generated by transforming the consumption of '*standard goods into an extraordinary experience'* (Pine & Gilmore, 1999).

In the domestic environment, there has been a loss of 'food culture', where food is provided only by big supermarkets with no outlets for local agricultural production (a process occurring in the northern Dodecanese – see Chapter 8). This loss of food culture has been referred to as a 'placeless foodscape' (see Morgan et al. 2006); where foods have become;

"homogenised into undifferentiated commodities, that simultaneously come from anywhere and nowhere"

Abbots and Lavis, 2013

It has also been argued to result in 'food deserts' (where nutritious food is difficult to obtain) according to Wrigley (2002) and Reynolds (2005). Over time, this has seen a rise of grass roots initiatives aiming to re-localise food systems and rebuild the link among producers and consumers in an *'interpersonal world of production'* (Morgan et al. 2006). This has been dubbed the '*reconnection perspective'* (Fonte, 2008) in which consumers seek to re-connect with 'place' through food products. In one recent study Autio et al (2013) found that consumers valued 'sustainable, healthy and tasty' locally produced food, and associated local food with craftsmanship and artisan production. This is of note to management of the Lispi SSCF supply chain, since in this environment, traditional foods are embedded in the local culture and the consumer preference towards them is a way of 'consuming nostalgia' (Autio et al, 2013), where consumers search for the 'real' or 'true' food that is embedded in the personal and shared social histories of place.

However, it must be noted that not everyone is interested in local foods at the destination (Cohen and Avieli, 2004) and the range of culinary experiences and tastes is broad (Björk and Kauppinen-Räisänen, 2014). Therefore, despite the image portrayed by many travel magazines (and some researchers), many tourists are not 'foodies' (Hall and Gössling, 2016) as defined as '*a person who devotes considerable time and energy to eating and learning about good food, however "good food" is defined'* (Johnston and Baumnann, 2015).

As Johnston and Baumann note, the term "foodie" is also often articulated with pejorative overtones' linked to "foodie privilege", especially in relation to the larger global food system. Therefore, the discussion over *'foodie culture, class and inequality' could arguably be translated into discussions of food and tourism replete as it is with issues of access democracy and distinction* (Hall and Gössling, 2016). To this end, Gössling and Hall (2013) suggested that tourism and hospitality, from both the production and consumption perspectives, need to be positioned in the context of a food system (what they referred to as a culinary system) in which food can be tracked from farm to plate, or in this case "Habitat to Consumer".

9.2 Aims and Objectives

This chapter focuses on the demand side drivers of seafood consumption including the following elements:

1. What are the seafood products (species) consumed on Lipsi? (*explore the product demand*)
2. Who is driving this demand? Is demand different between different groups e.g. tourists and locals? (*characterise the social drivers)*
3. Do some species of fish cost more than others? (*characterise the economic drivers*)

Objectives

1. To identify what the most purchased seafood products (species) are.
2. To identify if there are differences in consumer demand between Lipsi residents and visiting tourists.
3. To establish if there is a higher incentive to catch specific local species based upon their local economic value.

9.3 Materials and Methods

The data presented in this chapter was recorded by Visitor Exit Survey (for tourists) and Local Survey (for residents). Seafood financial values were recorded to contextualise the economic drivers of demand that promote the extraction of those species identified in Chapters 6 and 7 due to the expected economic return for those species at market. Together these data characterise the socio-economic context of consumers' behaviours on Lipsi and illustrate the broader context in which demand for products from the Lipsi Small-Scale Capture Fishery supply chain originates (Figure 176).

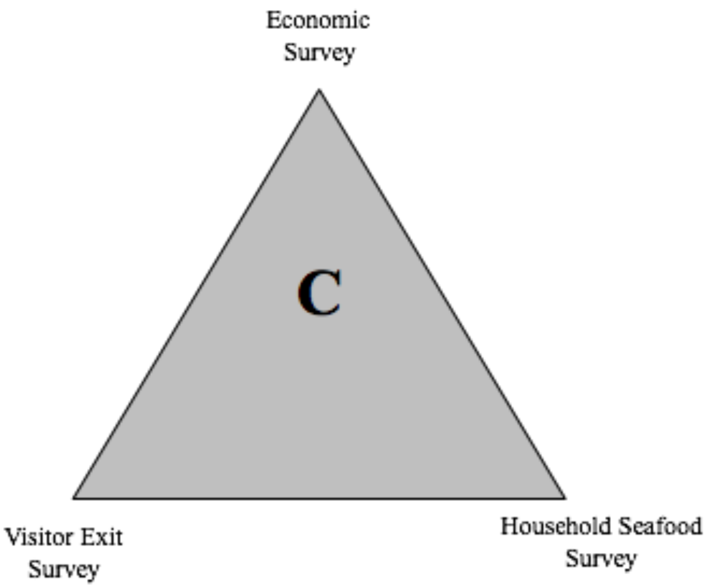

Figure 152. For a richer understanding of the Lipsi Consumers, a triangulated approach has been adopted incorporating investigation of Tourists seafood consumption, Resident seafood consumption, and attributed economic value

Survey Sites

Visitor Exit Surveys, Resident Household Surveys and SSCF Economic Surveys were all conducted in the general vicinity of the main population centre and Lipsi village. Informed consent was obtained from participants before conducting interviews, and residents, visitors and fishers were informed of the purpose of the research (Appendix _).

Visitor Exit Surveys were conducted between May and September 2014 (1 month either side of the peak Summer period) with tourists *leaving the island* from either; a) the Commercial Port or b) the Yacht Pier. Surveys were conducted in both locations to better represent the demographics of tourists who had spent time on the island. Household Surveys were conducted between May and September 2014 with residents; either in their households or in local cafés. Surveys were conducted with the assistance of a local translator to accurately communicate the survey task. The Small-Scale Capture Fishery Economic Survey took the form of a seafood financial value diary, with enquiries conducted frequently during landings data collection with participating fishers in order to capture fluctuations in product price (Figure 177).

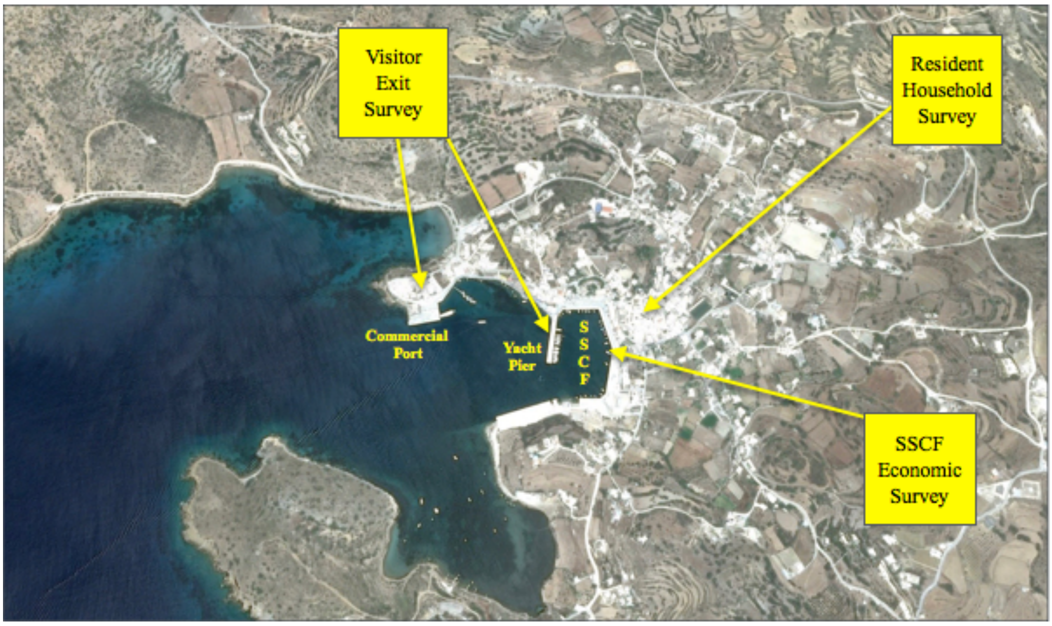

Figure 153. Satellite image of the Port of Lipsi illustrating the position of the Commercial Port, the Yacht pier, and the Small-Scale Capture Fishery vessels. Locations of the Visitor Exit Survey, Resident Household Survey and Small-Scale Capture Fishery survey also indicated.

9.3.1 Visitor Exit Survey

Visitor Exit Surveys included both domestic and international tourists. Individuals were approached by the author or by specially trained volunteers and were given information about the study (see Appendix) and then asked if they would participate in the study.

Survey times included both weekends and weekdays, morning and afternoons. (Table 61). Lipsi is well serviced in the summer months by ferries that pass between Patmos, Leros and Kalymnos and on the main ferry route from Piraeus (Athens). Out of season (Autumn, Winter, Spring) there is only the Piraeus ferry (Athens) and a three-weekly (Tue, Fri, Sun) ferry servicing these islands.

Table 48. Timetable for vessels leaving the island. Surveys were conducted in port from 30mins prior to departure. *Nisos Kalymnos runs year round, the rest are only present in the tourist season.

Company (Vessel)	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Private (Yachts)	AM	AM	AM	AM	AM	AM	AM
ABP Single Member PC (Anna Express NX 444)	08:00	08:00	07:30	08:00			
Blue Star Ferries (Patmos Star)	08:25 14:20		08:25 14:20				
ANEK Sealines (Nisos Kalymnos)*		08:05 20:00			08:05 20:00		10:15 20:40
Dodekanisos Seaways (Pride Dodekanisos)	13:00	13:00		13:00	13:00	13:00	13:00
Dodekanisos Seaways (Express Dodekanisos)			14:00				

Both the author and volunteers followed standard survey and interview protocols (see Appendix) that were prepared in advance. Visitors were asked demographic information pertaining to age, sex and nationality. Visitors were asked for their duration of stay on Lipsi and their seafood consumption habitats during this period (i.e. number of occasions / what kinds of seafood / where purchased). A final 'comments'; section was included to enable the documentation of more qualitative data (see VES form in appendix).

Not included in the Visitor Exit Survey were visitors departing on the BLUE STAR ferries to Rhodes; Tuesdays at 23:40, or to Port of Piraeus (Athens) Wednesday's at 00:45 due to their anti-social timings. All Visitor Exit Surveys were conducted in English, unless they were between volunteers and participants for whom which English was both a second language, in which case interviews were conducted in their first language. Visitor Exit Surveys were also conducted with recreational boat users. These were normally privately owned or leased sailing yachts or part of flotillas. Vessels were approached in the morning (usually between 08:00-10:00) on the quay (Figure 178), which has space for around 12-14 yachts, or on the pontoon which can accommodate 5-6 yachts.

Figure 154. Recreational boat users were also included in Visitor Exit Surveys, these were usually approached between 08:00 and 10:00 (Photo 14-06-2014)

9.3.2 Resident Household Survey

Resident Household Surveys were conducted to provide comparative date for the Visitor Exit Survey. The delineation of consumers into 'Visitors' and 'Residents' was deemed the most appropriate categories to establish for better understanding the seasonal drivers of seafood product demand on Lipsi. However, delineation could have been made by age, sex or any number of potential variables. Critical to the success, or otherwise, of the Resident Household Survey was the presence of a local translator to facilitate the process.

Resident Household Surveys were conducted with residents using a prepared questionnaire. Both the author, a local translator and volunteers followed standard survey and interview protocols. Residents were asked demographic information pertaining to age, sex and nationality. Residents were also asked for how long they had lived on Lipsi and their typical seafood consumption habitats (i.e. number of occasions / what kinds of seafood / where purchased). Critically, with regard to seafood consumption, residents were asked to list what their 'Top 5' *preferred* fish were in order to establish an idea of consumer driven demand for particular species. Preference was defined as:

"To like (one thing) better than another or others; tend to choose."

Oxford English Dictionary, 2016

A final 'comments'; section was included to enable the documentation of more qualitative data (see RHS form in appendix).

Surveys were conducted either in households or in local cafés from May until September 2014. Survey times included both weekends and weekdays, morning and afternoon periods. Surveys were targeted at individuals who had been living on Lipsi for over 90 days. Focus group techniques might be biased toward the opinion of a few outspoken or politically powerful participants (Morgan, 1993) and therefore all interviews were conducted in private to minimize the effects of other residents' presence on the answers. All interviews were conducted in partnership with a local translator who acted as a cultural broker after initial introductions had been facilitated by the head fisherman.

9.3.3 Small-Scale Capture Fishery Economic Survey

The Small-Scale Capture Fishery (SSCF) Economic Survey was on-going throughout the fisheries landings data collection phase (March – November 2014). The survey took the form of a 'diary' of the cost per/kg of landed SSCF species throughout the fishing season. Conversations about the 'current' cost of species / market price were continuously recorded with participating fishers from the Lipsi Small-Scale Capture Fishery. Data was recorded on an opportunistic basis depending upon landed catch. For example, if a fisher had landed several Saddled seabreams (*Oblada melanura*) on a particular fishing trip then that species might form the basis for enquiry on that occasion. Or, conversely if a fisher had landed a rarer species such as a Slipper lobster (*Scyllarides latus*) then the presence of the species in the catch provided an opportunity for discussion. Over the course of the fishing season (March-November) data pertaining to the financial value of reported species was recorded on more than one occasion, this was done to try to capture any seasonal fluctuations in the perceived financial value of landed SSCF species. Discussions were conducted in private (away from other fishers) to minimize the effects of another fisher's presence on the answers given.

9.4 Data Analysis

Demographic data
All mean summary statistics were calculated with their standard error.

Consumption data
Visitor Exit Survey and Resident Household Survey data were both categorised into 1 of 2 factor groups 'Tourist' and 'Resident'. All mean summary statistics were calculated with their standard error. ANOSIM and SIMPER were performed on the Top 10 most frequently report families for both Tourist and Resident, using (x+1) root transformed data. This was used to analyse any differences in tourist and resident seafood consumption patterns. ANOSIM results are presented with the *p*-

value (significance levels) and an R-value (the strength of the factors on the samples).

Analysis of differences in reported food consumption patterns between tourist and residents was conducted using multi-variate non-metric multidimensional scaling ordination (MDS) and Bray-Curtis cluster analysis using the computer package PRIMER 7 (Clarke & Gorley 2015). The Bray-Curtis similarity index was applied on square-root transformed data (to down-weigh the influence of rare and extremely abundant species) and to generate a rank similarity matrix, which was then converted into an MDS ordination. To check on the adequacy of the low-dimensional approximations seen in cluster and MDS the use of PRIMER 7 enabled clusters to be superimposed upon the MDS ordination (Clarke & Gorley 2015). A 2-way analysis of similarities (ANOSIM) was used to investigate differences identified from MDS and CLUSTER (Clarke & Gorley 2015).

Economic data

All seafood product prices are presented as reported. Purchasing Power Parity data provided by World Bank (2011-2015)

9.5 Results

9.5.1 Visitor Exit Survey

General description of tourist consumption patterns

A total of 723 Visitor Exit Surveys (♂; n=376, 52.0%, ♀; n=347 48.0%) were conducted with tourists to Lipsi between March-November of 2014 by the author and trained volunteers who between them spoke English, French and Spanish fluently. Twenty-seven nationalities were recorded in Visitor Exit Surveys (Figure 179). The biggest percentage of tourists surveyed were Italians (25.2%), followed by English (14.5%), Germans (12.2%), French (9.4%) and domestic Greek tourists (7.5%). Outside of the proximal countries of the European Union the most frequent visitors surveyed were from Australia (1.9%), Israel (1.8%) and the United States (0.7%).

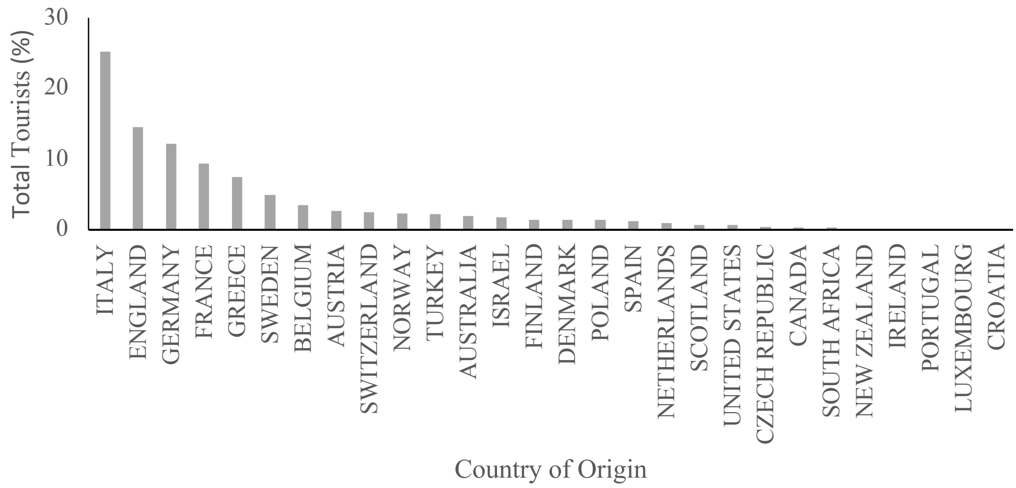

Figure 155. Percentage of visitors to Lipsi from different countries recorded by Visitor Exit Survey.

The most frequent age of tourists surveyed was the 50-59 years' bracket (27.7%), followed by 40-49 years' (27.1%) and 30-39 years' (22.8%). Together these three age groups accounted for over three quarters (77.6%) of all visitors to Lipsi (Figure 180). Minors are excluded from the data set with all respondents over the age of 18 and answering in a personal capacity. The mean amount of time tourists spent on

Lipsi was 6.0 (±0.3) day's (Median = 4; Range 1 day to 90 days). The mean reported number of seafood meals per stay was 3.4 (±0.2) (Median 2).

Overall, 571 respondents (79%) of tourists reported consumption of seafood products during their stay on Lipsi. 152 respondents (21.0%) reported no purchase of seafood, and 50 respondents (6.9%) reported consumption of some unspecified seafood. Tourists reported the primary source for obtaining seafood on the island to be from restaurants (77.0%). Only 17 respondents (2.4%) reported purchasing seafood products from a shop and just 23 respondents (3.2%) reported purchasing seafood from the local fishers. Six respondents (0.8%) reported fishing or independently spearfishing for seafood themselves.

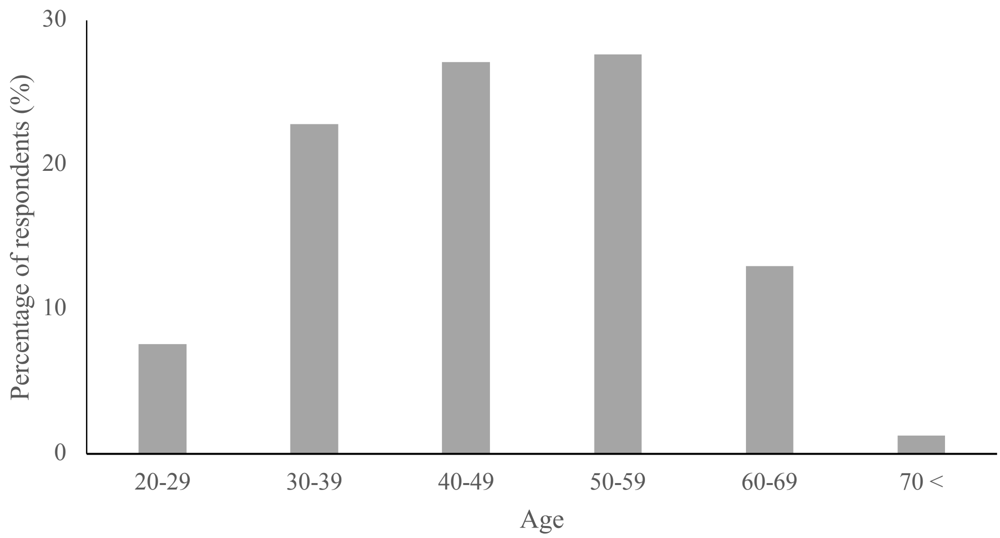

Figure 156. Percentage of respondents from each age range who responded to the Lipsi Visitor Exit Survey.

Overall 38 species, from 28 families were recorded from Visitor Exit Survey. However, unlike with Resident Household Surveys, most tourists' 'seafood literacy' (the ability to identify species consumed) was limited. Therefore for many seafood products they are only able to be classified at the taxonomic level of family (or higher) rather than at species level, with species specific identifications limited to 'iconic' local seafood products such as the Gilthead seabream (*Sparus aurata*), the White seabream (*Diplodus sargus*) and the Common dentex (*Dentex dentex*) or where there are only one species present in the family e.g. *Sparisoma cretense* in the Scaridae (Parrotfish) or *Xiphias gladius* for the Xiphiidae (Swordfish).

Top five most regularly consumed seafood products by tourist.

The top five families frequently contributing to tourist seafood consumption on Lipsi are the Octopus (Octopodidae; 43.2%) (Figure 181), Prawns (Penaeidae; 30.5%), Seabreams (Sparidae; 27.2%), Swordfish (Xiphiidae; 17.6%) and the combined Squid and Cuttlefish (Loliginidae, Omastrephidae and Sepiidae; 15.2%).

Whilst through this survey it was not possible to elicit the specific species that were being consumed, it was possible to report the contributions of species. For example, the Gilthead seabream (*Sparus aurata*) was the largest contributor to tourist seabream consumption (15.4%), whilst the European seabass (*Dicentrarchus labrax*) and 5.5% the White seabream (*Diplodus sargus*) at 5.4% also contributed. Anecdotally, Giant Tiger Prawns (*Penaeus monodon*) were reported to be one of the highest contributors to Prawn consumption, and the European blue mussel (*Myilus edulis*) to be the dominant contributor to mussel consumption, although there is no way of quantitatively verifying this data.

Figure 157. Octopus (Octopodidae) was the most frequently reported seafood product for tourist consumption.

Table 63 presents those species that were reportedly consumed by tourists. For classification, seafood products are generally grouped into Family taxonomic categories because seafood products were not identifiable to species level. The specific Greek seafood product groupings are again included for reference.

Table 49. Species which were included in a 'Top Five' most regularly consumed seafood species as established by Visitor Exit Survey (*) denotes produce generally unavailable from the Small-Scale Capture Fishery. The five most commonly reported seafood products are highlighted in grey.

SEAFOOD DESCRIPTION	GREEK (PHONETIC) SEAFOOD GROUPS	SEAFOOD SPECIES	TOURIST TOP FIVE (%)
Smelt & Anchovy	Αθερίνα (Atherína) Γαύρος (Gavros)	Atherinidae sp, Engraulidae sp.	3.2
Squid & Cuttlefish	Καλαμάρι (Kalamari) Σηπία (Soupia)	Loliginidae sp. Ommastrephidae sp. Sepiidae sp.	15.2
Octopus	Χταπόδι (Chtapothi)	Octopodidae sp.	43.2
Needlefish	Ζαργάνα (Zarghana)	*Belone belone*	0.1
Sardine	Σαρδέλα (Sardeles)	Clupeidae sp	1.2
Codfish*	Γαδόμορφα (Gadómorfa)	Gadidae sp.	2.5
Seabass	Λαβράκι (Lavraki)	*Dicentrarchus labrax*	5.5
Goatfish	Κουτσομούρα (Barbouni)	Mullidae sp.	3.9
Mussel	Μύδι (Mýdi)	Mytilidae sp.	7.4
Oyster*	Στρείδι (Streídi)	Ostreidae sp.	0.4
Lobster	Αστακός (Astakos)	Palinuridae sp. Scyllaride sp.	2.6
Urchin*	Αχινός (Achinós)	*Paracentrotus lividus*	2.0
Prawns*	Γαρίδα (Garída)	Penaeidae sp.	30.5
Crab*	Κάβουρας (Kávouras)	Portunidae sp.	0.4
Ray	Σαλάχι (Saláchi)	Rajidae sp.	1.6
Salmon*	Σολομοειδή (Solomoeidí)	Salmonidae sp.	2.5
Parrotfish	Σκάροι (Skaros)	*Sparisoma cretense*	0.6
Mackerel & Tuna	Mixed sp.	Scombridae sp.	2.9
Scorpionfish	Σκορπιός (Scorpio)	Scorpaenidae sp.	0.1
Grouper	Ροφός (Rofos)	Epinephelus sp.	0.1
Rabbitfish	Γερμανικά (Germanos)	Siganidae sp.	0.8
Seabream	Mixed sp.	Sparidae sp.	27.2
	Συναγρίδα (Sinaghritha)	*Dentex dentex*	1.7
	Σαργός (Sargos)	*Diplodus sargus*	5.4
	Τσιπούρα (Tsipoúra)	*Sparus aurata*	15.4
Shark	Καρχαρίας (Karcharías)	Unknown.	2.2
Swordfish	Ξιφίας (Xifias)	*Xiphias gladius*	17.6
John Dory	Χριστόψαρο (Christopsaro)	*Zeus faber*	0.3

9.5.1 Resident Household Survey

General description of household consumption patterns

A total of 123 household surveys (♂; n=64, 52.0%, ♀; n=59, 48.0%) were conducted with Lipsi residents between March-November of 2014. The adult who was 'generally responsible' for food preparation was targeted for survey.

The biggest percentage of household residents surveyed (90.2%) identified as Greek, followed by Italian (2.4%), English (2.4%) and German (1.6%) French, Norwegian, Danish and Finnish people made up the remainder (0.8%) of. The mean amount of time residents had been living on the island was 27.7 (±2.0) years

The mean amount of time spent living on the island for household participants was 27.7 years (±2.0); range; 20-87 years, with a broad age spectrum of the island surveyed (Figure 182). The mean reported number of seafood meals per week was 2.6 (±1.8); range 1-7 meals per week.

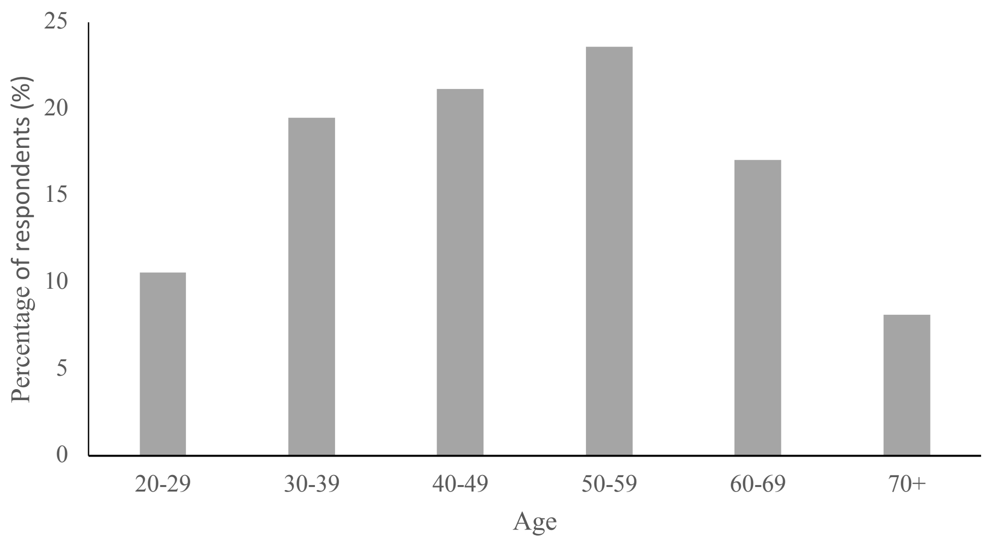

Figure 158. Percentage of respondents from each age range in the Resident Household Survey.

Overall, 97.6% of households reported consumption of seafood products. Households reported the primary source for obtaining seafood on the island to be from the small-scale fishing fleet (91.1%). Roughly one quarter of households were directly involved in the capture process (27.6%), with over three-quarters of households sourcing seafood directly from the fishers (75.6%). Around one in eight households' primary source of seafood was from local shops (12.2%) or a little under one in ten when eating in island restaurants (8.9%). Only three households reported no consumption of seafood (2.4%).

Overall 46 species, from 25 families were recorded at least once as one of the top five seafood species consumed in each household. A further 4 families of fish were not available from the small-scale fishery and were purchased tinned or frozen from local retailers; these were Sardines (Clupeidae); top five in 5.7% of households, and Anchovies (Engraulidae); top five in 8.9% of households, Prawns (Penaeidae) top five in 2.4% of households) and Salmon (Salmonidae) top five in 1.6% of households. Tinned Mackerels and Tunas (Scombridae) also represented top five food fish in 6.5% of households although this family of fish was also available 'fresh' from the capture fishery.

Top five preferred seafood products by resident.

The top five seafood families preferred *by* residents of Lipsi households are the Seabreams (Sparidae) from 15 species (75.6%), the Parrotfish (Scaridae) from one species (44.7%), the Seabasses (Serranidae) from 3 species (41.5%), the Mackerels and Tunas (Scombridae); from 3 local species (38.2%) and supplemented by miscellaneous tinned products (6.5%), and Rabbitifsh (Siganidae) from two species (30.9%).

The top five seafood species preferred by residents of Lipsi households are the Mediterranean parrotfish (*Sparisoma cretense*) from 44.7% of households (Figure 183), the Comber (*Serranus cabrilla*) from 40.7% of households (Figure 184), the Dusky spinefoot (*Siganus luridus*) in 30.9% of households (Figure 185), the Saddled seabream (*Oblada melanura*) in 30.1% of households and the Gilthead seabream (*Sparus aurata*) in 28.5% of households.Notable seafood product provision also came from the local Scorpionfish (Scorpaenidae) (26.8%), from the Squid and Cuttlefish (Sepiidae / Loliginidae / Ommastrephidae; 39.9%), the Octopus (Octopodidae; 26.8%) and the Goatfish (Mullidae; 26.8%).

Table 62 presents a cumulative list of those species for those that were reported to be within each households Top 5 preferred seafood products. For classification seafood products are grouped into Species taxonomic categories when possible, or into Family taxonomic categories for those seafood products that are not commonly identified to the species level. The specific Greek seafood product groupings are included for reference.

During collection of the quantitative data discussion often turned to what is meant by ‘preferred’. Many household respondents cited affordability of seafood products as influencing their *preferred* choice of seafood, and therefore what species they demanded from the Lipsi Small-Scale Capture Fishery. Therefore, for consumers on Lipsi, *preference* for particular seafood species was influenced by what was ‘financially attainable’ and ‘realistic’, and not just what was desired.

Figure 159. The Mediterranean Parrotfish (*Sparisoma cretense*) which was the most frequently preferred species by residents of Lipsi as recorded by the Resident Household Survey

Figure 160. The Comber (*Serranus cabrilla*) was the second most frequently preferred species for household consumption.

Figure 161. The Dusky spinefoot (*Siganus luridus*) was the third most frequently preferred species for household consumption.

Table 50. All species included in a 'Top Five' preferred seafood species as established by Resident Household Survey. (*) denotes produce generally unavailable from the Lipsi Small–Scale Capture Fishery. Grey rows denote the 'Top Five' most regularly preferred species.

FAMILY	GREEK (PHONETIC) FOOD FISH GROUPS	SPECIES	HOUSEHOLD TOP FIVE (%)
Smelt & Anchovy	Αθερίνα (Atherína) Γαύρος (Gavros)	Atherinidae sp, Engraulidae sp.	9.7
Squid & Cuttlefish	Καλαμάρι (Kalamari) Σηπία (Soupia)	Loliginidae sp. Ommastrephidae sp. Sepiidae sp.	39.9
Octopus	Χταπόδι (Chtapothi)	Octopodidae sp.	26.8
Belonidae	Ζαργάνα (Zarghana)	*Belone belone*	1.6
Bothidae	Γλώσσα (Glossa)	Bothidae sp.	1.6
Clupeidae*	Σαρδέλα (Sardeles)	Clupeidae sp.	5.7
Labridae	Χειλού (Hhilou)	Labridae sp.	0.8
Moronidae*	Λαβράκι (Lavraki)	*Dicentrarchus labrax*	7.3
Mullidae	Κουτσομούρα (Barbouni)	Mullidae sp.	26.8
Palinuridae	Αστακός (Astakos)	*Palinurus elephas*	0.8
Penaeidae*	Γαρίδα (Garída)	Penaeidae sp.	2.4
Salmonidae*	Σολομοειδή (Solomoeidí)	Salmonidae	0.8
Scaridae	Σκάροι (Skaros)	*Sparisoma cretense*	44.7
Scombridae	Κολιός (Kolios)	*Scomber japonicus*	20.3

	Κοπανι (Kopani)	*Auxis rochei*	6.5
	Παλαμίδα (Palamitha)	*Sarda sarda*	17.9
	Miscellaneous.	Scombridae	6.5
Scorpaenidae	Σκορπιός (Scorpio)	*Scorpaena porcus*	12.2
	Σκορπιός (Scorpio)	*Scorpaena scrofa*	14.6
Scyllaridae	Κολοχτύπα (Kolochtipa)	*Scyllarides latus*	4.9
Scylorinidae	Γάτος (Gatos)	*Scyliorhinus canicula*	0.8
Serranidae	Ροφός (Rofos)	*Epinephelus spp.*	3.3
	Χάνος (Chanos)	*Serranus cabrilla*	39.0
	Πέρκα (Perka)	*Serranus scriba*	9.8
Siganidae	Γερμανικά (Germanos)	Siganidae sp.	30.9
Sparidae	Μένουλα (Menula)	*Spicara maena*	4.1
	Μαρίδα (Maritha)	*Spicara smaris*	8.9
	Γόπα (Gopa)	*Boops boops*	4.9
	Συναγρίδα (Sinaghritha)	*Dentex dentex*	12.2
	Μπαλάς (Balas)	*Dentex macrophthalmus*	3.3
	Σαργός (Sargos)	*Diplodus sargus*	17.9
	Καραγκιόζης (Podikosargos)	*Diplodus vulgaris*	4.1
	Μελανούρια (Melanuri)	*Oblada melanura*	30.1
	Φαγκρί (Fagri)	*Pagrus pagrus*	8.9
	Μουσμούλι (Musmuli)	*Pagellus acarne*	1.6
	Πελαγίσιο λιθρίνι (Kefalas)	*Pagellus bogaraveo*	2.4
	Λιθρίνια (Lithrini)	*Pagellus erythrinus*	16.3
	Τσιπούρα (Tsipoúra)	*Sparus aurata*	28.5
	Σκαθάρι (Skathári)	*Spondyliosoma cantharus*	2.4
Sphyraenidae	Λούτσος (Lutsos)	*Sphyranea spp.*	2.4
Xiphiidae	Ξιφίας (Xifias)	*Xiphias gladius*	0.8
Zeidae	Χριστόψαρο (Christopsaro)	*Zeus faber*	4.9

9.5.3 Small-Scale Capture Fishery Economic Survey

Over the course of the 2014 fishing season (Mar-Nov) Lipsi fishers were regularly asked about the price per kilogram (€/kg) of fish species landed in the SSCF. The market values for the species landed by the SSCF are presented in Table 64.

Table 51. Price of fish per kg for Lipsi Small-Scale Capture Fishery species. Price is shown as a range due to variations in price due to a) size; larger individuals command a higher price and b) season; supply and demand dictate local price fluctuations.

FAMILY	SPECIES	GREEK NAME (Phonetic)	ENGLISH NAME	PRICE (€/kg)
Belonidae	*Belone belone*	Ζαργάνα (Zarghana)	Garfish	3-4
Clupeidae	*Sardina pilchardus*	Σαρδέλα / Παπαλίνα (Sardeles / (Papalina)	Sardine	4-6
Labridae	*Spp.*	Χειλού (Hhilou)	Wrasse	3-5
Muglidae	*Spp.*	Κέφαλος (Kefalo)	Grey mullet	2-4
Mullidae	*Spp.*	Μπαρμπούνι (Barbounia)	Goatfish	20-22
Muraenidae	*Muraena helena*	Σμέρνα (Smyrna)	Moray	5-6
Phycidae	*Phycis phycis*	Σαλούβαρδος (Salùvarthos)	Forkbeard	5-6
Scaridae	*Sparisoma cretense*	Σκάρος (Skaros)	Parrotfish	7-10
Scombridae	*Auxis rochei*	Κοπάνι (Kopàni)	Bullet Tuna	7-8
Scombridae	*Sarda sarda*	Λακέρδα / Παλαμίδα (Lakerda / Palamitha)	Bonito	7-8
Scombridae	*Scomber japonicus*	Κολιός (Kolios)	Mackerel	4-9
Scombridae	*Thunnus alalunga*	Τόνος μακρύπτερος (Tònos makripteros)	Albacore Tuna	10-12
Scombridae	*Thunnus thynnus*	Ερυθρός τόνος (Tònos erithòs)	Bluefin Tuna	10-12
Scorpaenidae	*Spp.*	Σκορπιός (Scorpios)	Scorpionfish	7-13
Scylorinidae	*Scyliorhinus canicula*	Γάτος (Gatos)	Dogfish	5-6
Serranidae	*Spp.*	Ροφός (Rofos)	Grouper	23-25
Serranidae	*Serranus cabrilla*	Χάνος (Chanos)	Comber	4-6
Serranidae	*Serranus scriba*	Πέρκα (Perka)	Painted comber	5-7

Siganidae	*Siganus luridus*	Γερμανός (Germano)	Rabbitfish	2-4
Sparidae	Spicara maena	Μένουλα (Menula)	Blotched picarel	5-6
Sparidae	*Spicara smaris*	Μαρίδα (Marides)	Picarel	5-6
Sparidae	*Boops boops*	Γόπα (Gopa)	Bogue	3-5
Sparidae	*Dentex dentex*	Συναγρίδα (Sinaghritha)	Common dentex	20-25
Sparidae	*Dentex macrophthalmus*	Μπαλάς (Balas)	Large eye dentex	6-8
Sparidae	*Diplodus sargus*	Σαργός (Sargos)	Sargos	8-11
Sparidae	*Diplodus vulgaris*	Καραγκιόζης (Podikosargos)	Two striped seabream	7-8
Sparidae	*Oblada melanura*	μελανούρι (Melanuri)	Saddled seabream	6-12
Sparidae	*Pagrus pagrus*	Φαγκρί (Fagri)	Red porgy	20-25
Sparidae	*Pagellus acarne*	Μουσμούλι (Musmuli)	Axillary seabream	7-9
Sparidae	*Pagellus bogaraveo*	Πελαγίσιο λιθρίνι (Kefalas)	Blackspot seabream	6-8
Sparidae	*Pagellus erythrinus*	Λιθρίνι (Lithrini)	Common pandora	13-15
Sparidae	*Sparus aurata*	Τσιπούρα (Tsipoura)	Gilthead seabream	20-22
Sparidae	*Spondyliosoma cantharus*	Σκαθάρι (Skathàri)	Black seabream	8-10
Sparidae	*Sarpa salpa*	Σάλπα (Salpa)	Salema	5-7
Sphyraenidae	Spp.	Λούτσος (Lutsos)	Barracuda	12-13
Triakidae	*Mustelus mustelus*	Γαλέος (Galeos)	Shark	5-7
Xiphiidae	*Xiphias gladius*	Ξιφίας (Xifia)	Swordfish	14-15
Zeidae	*Zeus faber*	Χριστόψαρο (Christopsaro)	John Dory	10-12
Lolingindae	*Loligo vulgaris*	Καλαμάρι (Kalamari)	Squid	5-10
Octopodidae	*Octopus vulgaris*	Χταπόδι (Chtapothi)	Common octopus	5-10
Sepiidae	*Sepia officinalis*	Σουπιά (Soupia)	Cuttlefish	5-8
Palinuridae	*Palinurus elephas*	Αστακός (Astakos)	Spiny lobster	25-35
Scyllaridae	*Scyllarides latus*	Καραβίδα (Karaviedes)	Slipper lobster	25-35

9.5.4 Triangulation of Visitor, Resident and Economic Data

Differences in Household and Tourists seafood product demand

To understand any differences in demand for seafood products between tourists and island residents a 'Top 10' of household 'preferred' and tourist 'consumed' species was created. This was achieved by ranking the ten most frequently reported species '*consumed by tourists'* in the Visitor Exit Survey and by ranking the ten most frequently reported species '*preferred by residents'* in the Resident Household Survey. Since tourists were unable to identify seafood products to species level, the data is presented for comparison at the broader family or common descriptive groupings level (in italics) depending upon which was the most acceptable and accurate term for legitimate comparison (Table 65).

Table 52. Rank Top 10 seafood families consumed by Households and Tourists. Percentages (%) represent percentage frequency reported. 'Bold' signifies families not available locally from the Lipsi Small Scale Capture Fishery supply chain. '*' signifies seafood products supplemented from outside of SSCF supply chain. Families and descriptive groupings (italics) are present in both the Residents and Tourist Top 10 are highlighted in grey.

Rank	Resident Household Survey		Visitor Exit Survey	
Top 10	Family	(Occasions %)	Family	(Occasions %)
1	Sparidae	75.6	Octopodidae	43.2
2	Scombridae*	44.7	**Penaeidae**	30.5
3	Scaridae	44.7	Sparidae	27.2
4	Serranidae	41.5	Xiphiidae*	17.6
5	*Squid & Cuttlefish**	39.9	*Squid & Cuttlefish**	15.2
6	Siganidae	30.9	**Mytilidae**	7.4
7	Octopodidae	26.8	**Moronidae**	5.5
8	Mullidae	26.8	Mullidae	3.9
9	Scorpaenidae	26.8	**Gadidae**	3.6
10	*Smelt & Anchovy**	9.7	Scombridae*	2.9

Five families/ descriptive groupings were present in both Residents and Visitors 'Top 10' of the most frequently consumed seafood products; Seabreams (Sparidae), Octopus (Octopodidae), Goatfish (Mullidae), Mackerels and Tunas (Scombridae) and *Squid and Cuttlefish* (Mixed species). Five families/ groupings were unique to the Rank Top 10 for both groups Residents and Visitors (Table 65).

For Visitors, four of these families were either imported or farmed (i.e. unavailable from the Lipsi Small-Scale Capture (SSCF) Fishery supply chain) these were; Prawns (Penaeidae), Mussels (Mytilidae), Temperate bass (Moronidae) and Codfish (Gadidae). In comparison, all ten families preferred by residents were available from the Lipsi Small-Scale Capture Fishery.

For Residents, five families/groupings were unique to household consumption, these were; the Parrotfish (Scaridae), the Seabass (Serranidae), the Rabbitfish (Siganidae), the Scorpionfish (Scorpaenidae) and miscellaneous *Smelt and Anchovy* (Mixed species).

In contrast, for Tourists, Swordfish (Xiphiidae) was the only unique family recorded by the Visitor Exit Survey, as a species commonly consumed by tourists. Although this species was not recorded in the Lipsi SSCF dataset in Chapter 7, this species was landed by fishers from the Lipsi SSCF.

Statistical analysis (below) revealed these differences in seafood consumption patterns to be statistically significant suggesting two distinct types of consumer are present on Lipsi.

MDS Ordination

Multidimensional scaling ordination (MDS) showed clear differentiation (separate clustering) of Resident Household Survey data - illustrated by 'H' for Household, and Visitor Exist Survey data denominated by 'T' for Tourist. This highlights the differences in those seafood products that were in demand by island residents in their households and those provided to tourists visiting the island.

In Figure 186 Resident Household Data (n=123) is represented by 'H' (grey), and by Visitor Exit Survey (n=723) tourist data by 'T' (navy).

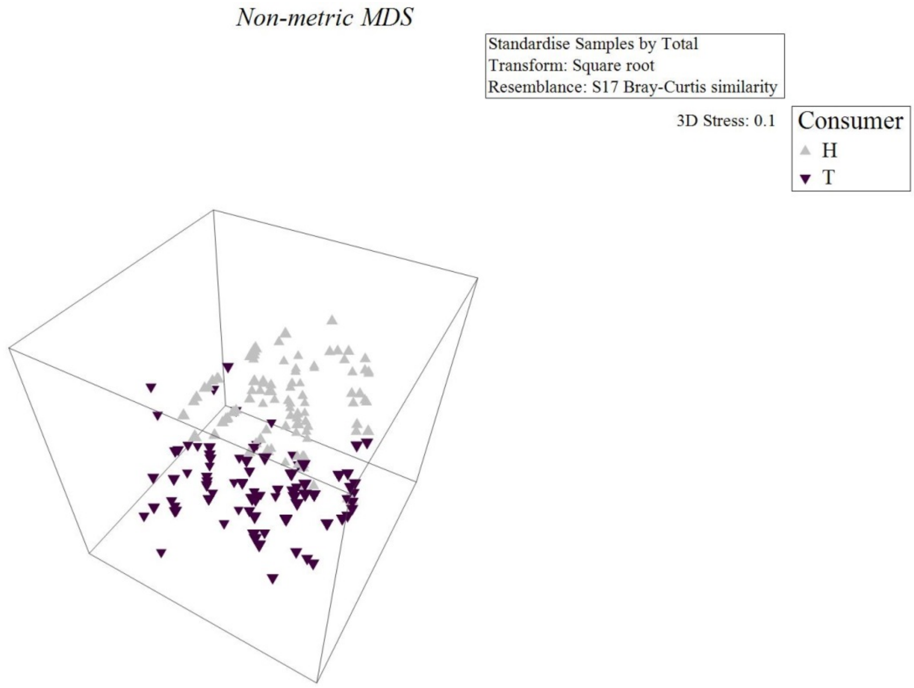

Figure 162. A 3D NMDS configuration for of seafood product choice as established by Visitor Exit Survey and Resident Household Survey for Lipsi island, Greece.

The 3D ordination of data points reveals that the seafood products that are being demanded by island residents markedly differ from those being demanded by tourists, although there is some overlap (Figure 186). One-Way ANOSIM revealed these differences to be both large and significant (Global R = 0.595, $p > 0.001$).

Further NMDS interrogation of potential variations in consumer demand was conducted for the following factors; Consumer *Sex* (Male or Female) and Consumer *Age* (20-29, 30-39, 40-49, 50-59, 60-69, 70+). Consumer origin was interrogated using two criteria; Consumer *Proximity* (Greek, Mediterranean, Non-Mediterranean) and Consumer *Nationality* (Greek Resident, Greek Tourist, Other) (Figure 187);

Consumer Sex **-** MDS ordination showed little differentiation between seafood products consumed by Males 'M' and Females 'F' (Figure 187a). Pairwise

ANOSIM revealed no significant difference is seafood consumption (Average R > 0.001, $p = 0.497$)

Consumer Age - MDS ordination showed little differentiation between seafood products consumed across age groups (Figure 187b). Test for differences between unordered age groups revealed no significant difference is seafood consumption (Average R > 0.001, $p = 0.187$). Here all pairwise tests also revealed a lack of significant differences across groups with the exception of the age groups 40-49 and 50-59 in which a significant difference ($p = 0.013$) of seafood product consumption was detected. However, this difference was small (R = 0.037).

Consumer Proximity - MDS ordination showed marked differentiation between seafood products consumed across proximity groups (Figure 187c). Test for differences between unordered age groups revealed a significant difference is seafood consumption (Average R = 0.220, $p > 0.001$). Pairwise tests revealed the greatest differences in seafood product consumption between Greeks and those of 'Non-Mediterranean Origin' (R = 0.459, $p > 0.001$), but also between Greeks and others of 'Mediterranean Origin' (R = 0.313, $p > 0.001$). However, no significant difference was detected between non-Greeks.

***Consumer Nationality* -** MDS ordination showed marked differentiation between seafood products consumed across nationality groups (R = 0.407, $p > 0.001$) (Figure 187d). Pairwise tests revealed the greatest differences in seafood product consumption between Resident Greeks and non-Greeks (R = 0.592, $p > 0.001$), but also between Tourist Greeks and Resident Greeks (R = 0.317, $p > 0.001$) . No signitifant difference was detected between Tourist Greeks and Non-Greeks (R = 0.012, $p = 0.355$).

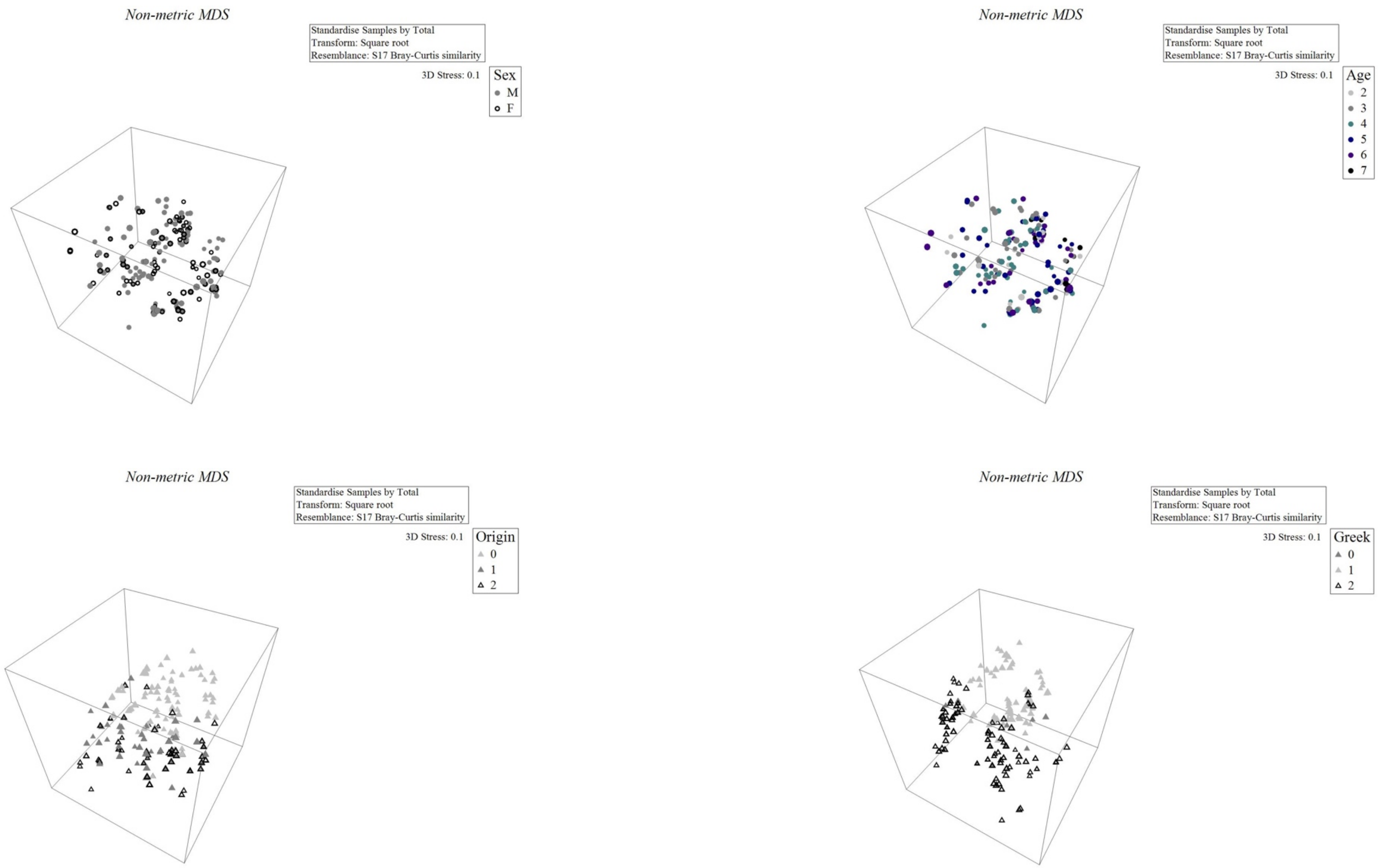

Figure 163– A 3D NMDS configuration for of seafood product choice as established by Visitor Exit Survey and Resident Household Survey for Lipsi island, Greece

Purchasing Power Parity

Although difficult to quantify (no quantitative data could be collected on surveyed consumers spending power), personal experience from nine months of living on the island amongst the community has informed the conjecture that proposes that the dissimilarities in seafood product consumption (and therefore differences in demand for seafood products from the Lipsi Small-Scale Capture Fishery supply chain) might also be driven by differences in spending power between island residents and visiting tourists.

It is widely accepted that international travellers are sensitive to price (Crouch, 1992) and until the early 1990s, there was little information on how the prices of goods and services that tourists purchase compare between countries (Dwyer et al., 2000). However, international comparisons of prices have been much more readily available in recent times with various illustrations of the Purchasing Power Parity (PPP) experienced between nations. Some of the greatest success in explaining this phenomenon has been informal; ranging from a *Tall Late Index* of Starbucks coffee (The Economist, 2004) to the *Billy Bookshelf Index* (Svenska Dagbladet, 2009). Choosing to holiday in Greece might therefore be linked to the ability to spend whilst there, instead of, for example choosing to holiday in Switzerland.

The best-known version of these informal PPP indicators is the 'Big Mac Index', published first in 1986, and each year since by 'The Economist' magazine, which shows the price of a 'Big Mac' burger in numerous different countries e.g. $6.82 in Switzerland (≈6.50 Swiss Francs) versus $0.67 in Venezuela (≈4.22 Venezuelan Bolivar). The Big Mac Index is published as an informal way of measuring the purchasing power parity (PPP) between two countries, and provides a test of the extent to which market exchange rates result in goods costing the same in different countries.

Whilst the Big Mac index as a reasonable real-world measurement of purchasing power parity (Cumby, 1996; Chen et al, 2007) it obviously comes with some limitations (see Pakko and Pollard, 2003 for discussion), and more rigorous studies of overall consumer prices in different countries are available (Summers & Heston, 1991; Crucini and Landry, 2012). Regardless of the methods used, these PPP indices enable is a 'ranking' of countries based on the relative national purchasing power of individuals from each nation (PPP per capita). What this means is that inhabitants of one nation (based on their average salary) can purchase more than the inhabitants of another (based on their average salary), even within a currency union e.g. Eurozone.

Table 66 shows the relatively low PPP of Greeks in comparison to other tourist nationalities identified by the Visitor Exit Survey. Whilst this table doesn't consider economic inequality within nations, the relatively poor purchasing power of 'average' residents in comparison to 'average' tourists is predicated on the logic that tourists are likely to be those individuals (from any nation) who have the disposable income necessary to facilitate an international holiday. Therefore, when both social groups exist together in the same place (e.g. Lipsi) the tourists are likely to be able to 'outspend' the locals when it comes to the purchase of seafood products whilst also creating supply chain demand for more expensive (and imported) species that may not otherwise exist.

Table 53. Countries recorded in Visitor Exit Survey by GDP (PPP) per capita. All figures are in current Geary-Khamis dolars, more commonly known as international dollars (Int$) and using World Bank (2011-2015) data.

RANK	COUNTRY	INT$
1	Luxembourg	101,925
2	Ireland	65,197
3	Norway	61,197
4	Switzerland	61,086
5	United States	56,116
6	Netherlands	48,313
7	Austria	48,194
8	Germany	47,377
9	Sweden	46,704
10	Denmark	46,624
11	Australia	45,501
12	Canada	44,310
13	Belgium	44,093

14	United Kingdom	41,459
15	Finland	40,979
16	France	39,631
17	New Zealand	36, 982
18	Italy	36, 030
19	Israel	35,831
20	Spain	34,527
21	Czech Republic	32,759
22	Portugal	29,213
23	**Greece**	**26,631**
24	Poland	26,261
25	Croatia	21,881
26	Turkey	19,609
27	South Africa	13,209

9.6 Discussion

Supply chains are not static – they evolve and change in size, shape and configuration, and in how they are coordinated, controlled and managed (MacCarthy et al., 2016). In the context of Sustainable Supply Chain Management (SSCM) of the proposed "Habitat to Consumer" seafood supply chain framework, it is important to have, not just a contemporary understanding of the demand side drivers of extraction (i.e. what products [species] are currently in demand, and from where that seafood product demand is coming [consumers]), but an informed projection of how the supply chain will likely be configured among others in the marketplace into the future i.e. an understanding the trend towards the 'internationalisation' and 'supermarketisation' of Greek supply chains explored in Chapter 8.

Tourist menus across the region advertise a whole range of non-Small-Scale Capture Fishery seafood products – (Figure 188), and this choice architecture directly effects the decision making of consumers on what seafood products to buy. The findings from each of the surveys in this Chapter and the implications for the SSCM of the Lipsin SSCF are discussed below.

Figure 164. Tourist menu offering "Shrimps", "Salt Cod" and "Mussels" none of which are provided by the Small-Scale Capture Fishery supply chain.

Visitor Exit Surveys are extensively used within the tourist industry (March and Woodside, 2005) to collect data ranging from total visitor volumes, to demographics and trip profiles (purpose of trip), but using them to elicit consumer behaviour in relation to sustainable seafood supply is novel.

In recent decades, the growth of tourism on Lipsi (and across the northern Dodecanese) has created a seasonal demand for seafood products that has not previously existed. Whilst it has not been possible to obtain data pertaining to the annual visitation numbers for Lipsi itself, a conservative estimation would easily put the number at greater than 10,000, the bulk arriving in the summer months (for comparison over 1.5 million visitors arrived in Kos in 2014 (Greek Reporter, 2014). This represents an order of magnitude more mouths to feed during this busy summer period. Visitor Exit Surveys thus represent a simple, yet effective method for collating data pertaining to visitor demographics. In this chapter, the questions were targeted specifically towards seafood consumption patterns and have identified that tourists tend to consume a different suite of seafood products to island residents.

The Visitor Exit Survey data presented in this chapter suggests that 'tourists' may bring with them to Lipsi food preferences and food cultures that are not linked to *'the desire to experience a particular type of food or the produce of a specific region…'* (Hall et al., 2003), but are instead more linked to food cultures born from supermarketisation, and the creation of an internationalised, 'placeless' foodscape where desired seafood consumption is at least partially *"homogenised into undifferentiated commodities, that simultaneously come from anywhere and nowhere"* (Abbots and Lavis, 2016). The popular tourist species of global (and farmed) origin were the Prawns (Penaeidae), Mussels (Mytilidae), Temperate bass (Moronidae) and Codfish (Gadidae) and which cannot be linked to any notion of food tourism.

Resident Household Surveys represented a simple, yet effective method for collating data pertaining to resident demographics and seafood preference, whilst enabling social integration of the researcher into the island community. In contrast to the Visitor Exit Survey, the Resident Household Survey elicited a household seafood culture orientated around seafood species that are available from the Lipsi Small-Scale Capture Fishery (SSCF). All of the Top 10 *preferred* species were available from the Lipsi SSCF with the most popular non-SSCF species being seafood products of squid and cuttlefish (39.9%) and Octopus species (26.8%) that may have been used to supplement domestic SSCF supply (e.g. Ommastrephidae, Sepiidae, Loliginidae, Octopodidae). The only ‘premium’ fish in the household top five is the Gilthead seabream (*Sparus aurata*) which is was commonly available at around €9-10/kg for locally farmed products (in comparison to 20-22€10/kg for wild caught fish from the Lipsi SSCF – see 10.5.3).

When the Visitor Exit Survey and Resident Household Survey data was combined, the Multidimensional scaling (MDS) data suggests that it is the process of ‘tourism’ itself, regardless of consumer sex, age, or origin that most influences seafood product consumption, and therefore demand on the seafood supply chain. This finding lends weight to previous research that suggests that vacationers in Greece (Leontido 1994) and tourists more generally (Carr, 2002) exhibit attitutes and beviours when abroad that might be quite different to those in their home environment. This information can potentially help inform seafood supply chain managers about how to market particular products to appeal to ‘tourists’, and thus potnetially manipulate demand to better meet supply in the Lipsi SSCF supply chain.

Economic or ‘pricing’ surveys are often of interest to supply chain managers who need to understand consumer choice behaviour and specifically the likelihood of demand increasing, or decreasing, depending on the change of price of a product. In its simplest form, *demand economics* relies on the principle that a consumers’ willingness to pay a price for a specific seafood product (holding all other factors constant) is based on the concept that a decrease in the price of the product will increase the demand, and vice versa. Alternatively, an increase in the *supply* of the product will decrease the price, and vice versa.

9.6.1 Relevance to the Small-Scale Capture Fishery Sustainable Supply Chain Management

In the Lipsi SSCF supply and demand for products is dictated by both supply and demand, for example the Saddled Seabream (*Oblada melanura*) might fetch €6-7 in May and June when the fish are abundant in the seascape, but as much as €11-12 in August when supply is lower and demand at its peak. In addition to these product fluctuations, it is also important to establish the cultural 'hierarchy' for seafood products. Through pricing surveys, it was possible to establish that locally the most esteemed (and therefore expensive) seafood products were the lobsters (*Palinurus elephas, Scyllaride latus*), the larger, and rarer, seabreams (*Dentex dentex, Pagrus pagrus*) and the grouper (Epinephelinae). Having access to this local knowledge can help contextualise consumer choice, in relation to consumer spending power and socio-cultural traditions.

For example, the Resident Household Survey reported some regular consumption of the 'cheaper' Seabream (Sparidae) species e.g. Picarel (*Spicara smaris*) which retails at 5-6€/kg or Bogue (*Boops boops*) which retails at 3-5€/kg. In contrast, the most commonly reported Sparidae in the Visitor Exit Survey were the White Seabream (*Diplodus sargus;* 8-11€/kg), the Common dentex (*Dentex dentex,* 20-25€/kg) and Gilthead seabream (*Sparus aurata,* 20-22€/kg). (NB – the extensively farmed Gilthead seabream is much cheaper than wild caught, priced around 5-7€/kg).

Another example is the low-cost Rabbitfish (*Siganus luridus*; 2-4€/kg) which is regularly sold to residents but rarely to tourist, whilst the high cost Swordfish (*Xiphias gladius;* 14-15€/kg) is a regular product for tourists but not residents. It may not all attributable to spending power however, since Scorpionfish (Scorpaenidae sp) cost between 7-13€/kg and are very popular amongst residents but not tourists. However, in this case it may be that both the common name and the appearance of the species is off-putting to tourists. (see Figure 189)

Figure 165. Scorpionfish (Scorpaenidae) are a popular family of fish amongst island residents but in not generally consumed by tourists.

There is a precedence for the successful marketing of seafood products through name changes. For example, the ‘Slime head’ (*Hoplostethus atlanticus*) was renamed the Orange roughy, the ‘Patagonian Toothfish’ (*Dissostichus eleginoides*) has been successful rebranded as the Chilean Sea Bass and the American ‘Gizzardfish’ (*Dorosoma cepedianum*) as Lake Whitefish.Goatfish (Mullidae sp) are also very popular amongst both groups and cost 20-22€/kg and therefore cultural ties to specific seafood species may also determine seafood product choice. Further research socio-economic research should be conducted to elicit these relationships.

Tourists visiting Lipsi create a demand for cephalopod consumption (Octopus, Squid and Cuttlefish) which is so high that the Small-Scale Capture Fishery fishers start targeting these species begins immediately after peak tourist season in September (see Chapter 8). This ensures that as many cephalopods as possible can be caught ahead of the following years tourist season, with fishers stockpiling cephalopods over the Autumn and Winter in their freezers and selling them in bulk to restaurants in Spring (One fisher sold 400kg to a Lipsi restaurant in 2014).

Eating cephalopods is a popular Greek tourist seafood tradition is often marketed with Ouzo, their popularity is expressed in mygreecetravelblog.com;

“As we quickly discovered, octopus and calamari (squid) are two items listed on the menu of practically every Greek tavern that serves seafood, especially in the Greek Islands. In fact, it’s common to see octopus hanging to dry outside tavernas in fishing villages or on streets close to harbour areas”

However, it is not just demand for cephalopods. Both seabreams and swordfish are also regularly consumed by tourists that seek to enjoy traditional produce from the local fishery. The demand for the esteemed Gilthead seabream (*Sparus aurata*) is such that it is now extensively farmed for both the domestic and export market (Papaharisis et al., 2016) and a recent stock assessment indicates that demand for Swordfish (*Xiphias gladius*) in the Mediterranean Sea has meant that the species is being fished between 13-40% over maximum sustainable yield (Natale et al., 2011).

9.6.2 Management Recommendations

For the informed and sustainable management of the Lipsi SSCF supply chain, it is important to understand these consumer trends, especially since the emergence of new seafood products, in particular prawns (Penaeidae), but also salmon, (Salmonidae), cod (Gadidae) and mussels (Mytildae) that are filling hitherto unfulfilled or novel marketplace niches (Figure 190).

Figure 166. The emergence of several Tiger Prawn (*Penaeus monodon*) supply chains from Asia, and their current success with tourists means that other supply chains, such as the Small-Scale Capture Fishery, are under threat from a decline in demand.

These modern, international seafood supply chains have emerged with the Supermarketisation of the marketplace (see Chapter 8) and yet the success of such seafood products in the marketplace can also cause the demise of and decline of other supply chains, where demand is no longer sufficient to drive the chain (MacCarthy et al., 2016).

A relative decline in demand for certain products (or in fact the capacity to supply) traditionally supplied by the Lipsi Small-Scale Capture Fishery (which would have supplied 100% of the island's seafood products at one point) has been confounded by fluctuating and changing demand for seafood with the internationalisation of the Marketplace making supply chain management decisions all the more difficult.

The changing patterns of lseafood consumption on Lipsi is likely to have been exacerbated over the last decades with the growth of Greek tourism (Telfer and Wall, 1996), the associated demand to meet both seasonal tourist seafood preferences, and evolving consumer demands linked to the neo-liberalisation of the marketplace, and substitution of local products with imported ones (Jenkins et al., 1998).

These changing supply chain demands have been, and are still, evolving against a backdrop of uncertain and diminished local supply (Tsikliras et al., 2013) and the capacity to source seafood from suppliers farther away from place than ever before (Norse et al., 2012; Watson et al., 2015). Further research is required into the volume and sustainability of imported seafood products to better understand the local economics before evidence-based management recommendations can be made.

9.6.2 Limitations and Future Research

A clear limitation to the data collected in this chapter is the lack of information pertaining to the 'purchasing power' of those consumers involved in the Visitor Exit Survey and Resident Household Survey. Without such information, there is no way of exploring statistically if those individuals with greater spending power are the same individuals who are purchasing the more expensive seafood products. Additionally, although it might well be assumed, there is no way of determining if it is the more affluent island residents who are demanding the more expensive seafood. For this reason, future research should include a metric for understanding the relative purchasing power of consumers and how that informs demand for seafood products.

CHAPTER 10 – Discussion, Synopsis and Management

The ‘Place-based Ecologically Dominant Sustainable Supply Chain Management Conceptual Framework’ presented in this thesis offers a conceptual framework for the investigation of place-based seafood supply (Chapter 4, Figure 56). The study interrogates the pre-catch elements of the supply chain (ecological system) but also identifies the barriers to sustainability present in the coastal fishery and from the wider socio-economic context (socio-economic system). Critically the study identifies both the risks to the supply chain but also the opportunities for risk mitigation and sustainable development in the context of the fishery as an extractive industry. This framework has been developed herein through the case study of the Lipsi Small-Scale Capture Fishery (SSCF) supply chain.

The conceptual framework provides a resource for both SSCF managers, and SSCF researchers to utilise to interrogate seafood supply chains at appropriate socio-economic and ecological scales. In other words, those seafood supply chains that are unique to a place. Under this conceptual framework, we move beyond ‘catch to market’ thinking, and emphasise the role of the coastal habitats unique to place as the principle provider of seafood product supply. Thus, Sustainable Supply Chain Management (SSCM) decisions need to satisfy criteria pertaining to the environmental sustainability which conserves this supply, prior to addressing social and economic criteria further along the supply chain – an Ecologically Dominant (ED) logic.

Presented in this final chapter is a summary of the research questions presented in this thesis, and main research answers for each of the five stages (Habitat, Assemblage, Fishery, Marketplace, Consumer) for the ‘Habitat to Consumer’ supply chain conceptual framework (Table 68). This is followed by (1) Discussion of the major themes and (2) a Synopsis of the work to ‘tell the story’ of the research. This is followed by (4) conclusions relating to major aspects explored and (4) potential management solutions pertaining to supply chain sustainability.

Table 54 - The main research questions (and sub research questions) relating to each of the five stages (Habitat, Assemblage, Fishery, Marketplace and Consumer) of the 'Habitat to Consumer' supply chain conceptual framework.

Main research questions	Sub research questions covered in chapters 5-9	Themes from literature / contemporary theory	Methods	Confirmed themes from lit / not found themes from lit / new emerging themes	Answer sub research Questions in chapters 5-9	Main research answers
Q1. What are the **habitats** found in the coastal seascape of Lipsi Island?	Q1a. What are the coastal habitats around Lipsi? Q1b. What is the relative extent and distribution of habitats in the seascape? Q1c. What is the biological health of the habitats?	Habitat mapping through local knowledge (*e.g. Teixeira et al., 2013)* Habitat mapping using small-scale Unmanned Aerial Vehicles *(e.g. Barrell and Grant, 2015)* Importance of knowing habitat extent / Fragmentation *(e.g. Roelfsema et al., 2014)* Importance of understanding habitat connectivity / habitat mosaics *(e.g. Nagelkerken et al., 2015)* Habitat resilience relating to biological conditon *(e.g. Unsworth et al., 2015)* Defining habitats for spatial management *(e.g. Giakoumi et al., 2011)*	**1. Traditional and Local Ecological Knowledge** Interviews with 3 Lipsi fishers to establish both a local habitat typology and an initial habitat map of the coastal zone at the island scale (~150km^2). **2. Aerial Remote Sensing** Flights over 9 bays around Lipsi using an Unmaned Aerial Vehicle. This is to create photo orthomosaics and to establish habitat distribution at the bay scale. **3. Seagrass-Watch Protocol** Four seasons of Seagrass-Watch at the same 9 bays around Lipsi. This is to establish in-situ habitat observations pertaining to biological health at the site scale (33 quadrats per site).	Confirmed theme – The benefits of collaborative engagement with Traditional and Local Ecological Knowledge in the marine environment *(see Thornton and Scheer, 2012).* Emerging theme – Use of optical imaging systems and lightweight drones for mapping marine habitats *(see Duffy et al., 2018)* Confirmed theme – Importance of ecosystem assessement to resource management *(see Cobben et al., 2012).*	A1a. The coastal habitats typology includes *Posidonia oceanica* seagrass meadows, rocky-algal reefs, coralline algae formations and unvegetated sandy bottoms. A1b. There are approximately ~3.41ha of *Posidonia oceanica* seagrass meadows, ~3.07ha of rocky-algal reef, ~5.71ha of unvegetated sandy bottoms across the 9 bays as mapped by Unmanned Aerial Vehicle. The bays show a definitive mosaic pattern and high connectivity is expected. A1c. The health of the habitats varies depending upon the location. Eutrophication contributes to poor seagrass health in Moschato Bay and anchoring to degraded seagrass meadows in Papadria Bay.	A1. The main habitats around Lipsi are *Posidonia oceanica* seagrass meadows, rocky-algal reefs and unvegetated sandy substrates in the shallow (<50m) coastal zone. Deeper than this (>50m) there is an additional habitat characterized by coralline algae formations.

Q2. What are the species **assemblages** associated with the coastal habitats around Lipsi**?**	Q2a. What is the abundance and diversity of species present in the coastal habitats? Q2b. How connected is the seascape i.e. is there species overlap between habitats? Q2c. What is the age and trophic structure of the species assemblage i.e. juvenile or adult individuals? Carnivores or herbivores?	Supply side variability in fish provisioning due to environmental factors. *(e.g. Harmelin-Vivien, 1994)* Ecosystem Service Providers and Fisheries Provisioning *(e.g. Manson et al., 2005)* Ecological Associations and habitat-linked Species *(Guidetti, 2000)* The importance of connectivity between coastal habitats *(e.g. Mumby et al., 2004)* Documenting fish utilisation of multiple coastal habitats *(e.g. Boström et al., 2011)* Food Web Interactions and positive or negative feedbacks *(e.g. Hamilton and Caselle, 2015)* Evidencing of the nursery role hypothesis *(e.g. Beck et al., 2001)*	**1. Baited Remote Underwater Video** 432 deployments of Baited Remote Underwater Video stations (60-minute deployments) over four seasons (n = 108 per season) to establish ecological associations. **2. Underwater Visual Census** 432 Undewater Visual Census Apnea Point Count (10-minute surveys) over four seasons (n = 108 per season) to establish ecological associations and individual species life history parameters (e.g. juvenile or adult). 432 Undewater Visual Census Apnea Belt Transect (10-minute surveys) over four seasons (n = 108 per season) to establish ecological associations and individual species life history parameters (e.g. juvenile or adult) **3. Catch and Release Nets** 486 Fyke Net deployments of ~12hrs each (~5,832hrs in total) over four seasons (~1458hrs per season) to establish ecological associations and individual species life history parameters (e.g. juvenile or adult). 324 Minnow Net deployments of ~12hrs each (~3,888hrs in total) over four seasons (~972hrs per season) to establish ecological associations and individual species life history parameters (e.g. juvenile or adult).	Confirmed theme – *Posidonia oceanica* seagrass meadows support a greater abundance and diversity of species than adjacent bare sand habitats *(see Kalogirou et al., 2010).* Confirmed theme – *Posidonia oceanica* seagrass meadows are 'high-prioirty' critical habitats for spatial management due to their high biodiversity and nursery role *(see Giakoumi et al, 2011)* Emerging theme – Importance of identifying locations and configuration of coastal habitats for Ecosystem Based Fisheries Management *(see Giakoumi et al., 2015)*	A2a. A total of 78 species from 28 families were identified by Underwater Visual Census and a total of 66 species from 28 families by Baited Remote Underwater Video. Furthermore, the species from the Congridae (*Conger conger, Gnathophis mystax*) Scorpaenidae (*Scorpaena porcus*), Scianade (*Sciana umbra*) and Scyllaridae (*Scyllarides latus*) were recorded by Catch and Release Nets. A2a. Multi-variate analysis showed differentiation, but overlap, between *Posidonia oceanica* seagrass meadow, rocky reef and unvegetated sandy bottom habitats. This suggests high connectivity between coastal habitat types. A3a. The individuals observed across the habitats of the coastal zone were predominantly juveniles of the species. Very few large Class D (predatory) species were recorded by any method.	A2. There is overlap between the ecological associaions of the three dominant habitat types (seagrass meadow, rocky-algal reef and unvegetated sandy bottom) in the coastal zone. The more comple habitats (seagrass meadows and rocky reef) are characterized by higher species diversity and abundance.

Q3. How do you characterise the Lipsi **fishery?**	Q3a. How, when and where are species extracted by the Lipsi fishery? Q3b. What species are being fished in the fishery? Q3c. What are the longer-term trends in species diversity and abundance as recalled by local fishers?	Local stock assessment / Habitat associations *(e.g. Kalogirou et al, 2010)* Complexity of multi-species multi-gear fisheries *(e.g. Tzanatos et al, 2005)* The importance of understanding the behavioural dynamics of fishers *(e.g. Salas and Gaertner, 2004)* Harnessing Fishers Ecological Knowledge and reporting Fishers Perceptions *(e.g. Coll et al, 2014)* Impact of fisheries on habitat integrity *(e.g. Puig et al., 2012)* Ecosystem Based Fisheries Management *(e.g. Moore e tal., 2009)*	**1. Reported Fishing Effort** 139 surveys over 3 seasons (41 in Spring, 59 in Summer and 39 in Autumn) to establish patterns of fishing effort relating to seasonal gear use, extraction patterns, habitat associaitons and fishing locations / sites) 2. **Fishery Landings Data** 139 surveys over 3 seasons (41 in Spring, 59 in Summer and 39 in Autumn) to establish data relating to catch abundance / frequency of specie and to life-history parameters (e.g. stock maturity and trophic level). **3. Fisheres Ecological Knowledge** Semi-structured interviews with 7 full-time fishers from Lipsi to establish temporal and spatial changes in seafood supply. The interviews are also an opportunity for the fishes to suggest management measures.	Confirmed theme – Spatio-temporal dynamics of small scales fisheries are complex and relate to resource availability *(see Forcada et al., 2010)* Confirmed theme – Fisheries reacts to both the ecological and social system through a series of linkages and feedback mechanisms *(see Kittinger et al., 2013)* Confirmed theme – Invasive species are profoundly affecting the distribution and abundance of key fishery species *(see Zenetos 2010)* Emerging theme – Improved data for small-scale fisheries could improve catch reconstruction efforts *(see Moutopoulos et al., 2015)*	A3a. A number of factors contribute to the decision of where and how to fish but there are three notable factors. 1 - the prevailing weather conditions (in particular the Meltemi wind) which directly affects the ability of fishers to fish in certain locations. 2 - the habitat-linked nature of particularly desirable foodfish species e.g. species of seabream from fishing in seagrass meadows or lobsters from coralline algae formations. 3 – the season and thus the abundance and maturity of certain seafood species. A3b. Landing data revelaed 69 different seafood species (31 familes) as present in fishers catch. The most abundant species was the invasive Dusky spinefoot (*Siganus luridus*). A3c. The Lipsi fishers lived experience reflects the regional trends from the region of overfishing and stock decline.	A3. The Lipsi fishery is similar to other small-scale capture in the fisheries Mediterranean Sea in that it operates on the continental shelf (<200m) in areas that can be reached with a few hours. The boats are generally active throughout the year and their fishing activity is characterized by a diverse array of gears. Fish products are also mostly destined for local sale.

Q4. What constitutes the **marketplace** for seafood products?	Q4a. What is the market infrastructure / seafood retailers available to the people of Lipsi? Q4b. What seafood products are available at market to purchase? Q4c. How are those seafood products that are available being presented to the consumer?	Exploring how small-scale fisheries contribute to food security and poverty reduction (e.g. Béné et al., 2016). The supermarketisation of the marketplace and the growth in the number of imported species. *(e.g. Cohen et al., 2013)* Investigating how the tools of choice architecture are present in seafood products, *(e.g Sunstein and Reisch, 2014)* Exploring the seafood products options presented to consumers *(e.g. Stamatis et al., 2005)*	**1. Choice Capacity Mapping** During a 'snapshot' survey in August 2014 conducted over ~2 weeks, the number, type and size of retailers were identified, counted and geographically located to establish 'Choice Capacity'. This is to establish the geographical locations and retail infrastructure for selling seafood products. **2. Choice Task Survey** During a 'snapshot' survey in August 2014 conducted over ~2 weeks, the diversity of species available to the consumer at market and record their place of origin was recorded. This is to establish the 'Choice Task' presented to consumers and the relative prevelance of imported species. **3. Choice Options Survey** During a 'snapshot' survey in August 2014 conducted over ~2 weeks, the manner of product presentation (e.g. frozen, canned etc) was recorded to establish 'Choice Options' and the nature of the seafood products presented to consumers.	Confirmed theme – The marketplace trend is for more, not fewer product options for consumers *(see Johnson et al., 2012).* Emerging theme – Across the northern Dodecanese, the modernisation ('supermarketisation') of supply chains is currently underway *(see Marglas et al., 2015)* Emerging theme – The capacity for sustainability orientated 'nudging' is evolving alongside the supermarketistaion of the marketplace *(see Smith and Zywicki, 2016)* Emerging theme – Imported species are creating a demand for seafood products that cannot be met by the fish stocks in local water. *(see Zeller and Pauly, 2016)*	A4a. The larger islands offered the consumer a greater variety of retailer and of products – principally through supermarkets or supermarket chain 'metro-markets'. The island of Lipsi itself offered a middle ground between the highy supermarketised neighbors of Patmos and Leros and the minimal infrastructure of Arki and Marathi. A4b. A total of 153 species from 59 families were documented across the retail outlets of the northern Dodecanese archipelago. Over twice the number of species (221.7% more) that were recorded from the small-scale capture fishery. A4c. As retail infrastructure improved, so to does the variety of products. Minimal infrastructure allowed for fresh or tinned products only. Larger modern outlets enabled retail of both imported and domestic products in refrigerated, fresh, tinned or frozen formats.	A4. Due to the highly connected nature of the northern Dodecanese islands the market 'place' for seafood products constituted the surrounding islands of the northern Dodecanease archipelago. The species available across the retail outlets were highly international (imports originated from 41 countires) and every ocean except the Artic and southern (Antartic) oceans.

Q5. What is driving the **consumption** of seafood products?	Q5a. What are the seafood products consumed on Lipsi? Q5b. Is demand for species different between particular social groups? Q5c. Do some species of fish cost more than others?	The changing nature of seafood product supply and the proliferation of invasive species *(e.g. Zeneteos et al., 2008)* The increasing diversity and amount of food that is imported for tourist consumption. *(e.g. Telfer and Wall, 1996)* Evolving relations between food, place and identity *(e.g. Erkus-Öztürk and Terhost, 2016)* The growth and development of 'food tourism' and the resulting consolidation of regional identities *(e.g. Everett and Aitchinson, 2008)* Economic considerations determining supply chain parameters *(e.g. Casson, 2013)*	**1. Visitor Exit Survey** Visitor Exit Surveys were conducted with 723 individuals between March and November 2014 to establish consumer demographics and seafood consumption patterns. **2. Household Survey** Residents of Lipsi participated in 123 household surveys between March and November 2014 to establish seafood consumption preferences and patterns. **3. Economic Survey** Continuious monitoring of the 'price per kilo' of common seafood products was conducted between March and November 2014. This was to establish comparative prices for different seafood species.	Confirmed theme – Small-scale fisheries are important contributors to seafood products destined for local sale (see Guyarder et al., 2013) Confirmed theme – The Gilthead seabream (*Sparus aurata*) is now a ubiquitous seafood product *(see Papaharisis et al., 2016)* Confirmed theme – Different economic values are ascribed to different seafood species, and both locals and tourists are sensitive to price *(see PPP discussion)* Emerging theme – Many tourists bring with them an international (or 'placeless') food culture and consume popular seafood species of global origin *(see Abbots and Lavis, 2013)*	A5a. On Lipsi the most commonly reported seafood products across resident and tourists orginiated from the Sparidae (Sea breams), Scombridae (Mackerels and Tunas), Scaridae (Parrotfish), Penaeidae (Prawns) and Octopodidae (Octopus) A5b. The seafood species consumed on Lipsi were distinct between 'Tourists' and 'Residents'. Tourists tended to consume Prawns, Seabreams, Swordfish, Octopus and Cuttlefish. In comparison, Residents preferred Parrotfish, Comber, Rabbitfish and two specific species of seabream – *Oblada melanura* and *Sparus aurata*. A5c. Different species of fish command different prices, as does the origin of the individual seafood product e.g. a wild Gilthead seabream commands a higher price than a farmed Gilthead seabream.	A5. There are multi factors that drive the demand for particular seafood products on Lipsi. The evolving nature of both the consumer and the supply chains makes it challenging to predict the future demands on seafood supply chains. It could be argued that the globalisaiton of supply chains will only serve to dissipate the demand for seafood products originating from the Lipsi small-scale capture fishery.

10.1 Discussion

It could be argued that, through the creation of 'demand' in the seafood supply chain it is the Consumer (and by proxy the Socio-Economic system, and not the Ecological System) that still dominates fishing industry thinking. In many respects this is logical because this is where the 'origin' in the demand for fishing occurs.

However, if supply chain managers are looking to ensure the sustainability of seafood supply chains, then they must make decisions that are *ecologically* rooted. Indeed, if in the future, our supply of seafood is to be truly sustainable, it is 'supply' that should be front and centre of supply chain decision making.

In many respects this logic, and the sustainability-oriented vision for supply chain management is reflected in some of the contemporary thinking surrounding a 'Sustainability Marketing' (see Belz and Peattie, 2010). Through adopting a consumer marketing focus, 'sustainability marketing' emphasises the integration of sustainability principles into both marketing theory and the practical decision making of marketing managers. Using this perspective, traditionally socio-ecological issues move from a 'constraint' in the marketing process (considered post strategy development) to a starting point on an equal footing with customer needs.

It is contested here that this way of thinking is reflected in the Ecologically Dominant Sustainable Supply Chain Management conceptual framework presented in Chapter 4. Here, the indefinite capacity for the future provision of a product from 'Habitat' to 'Consumer' along the seafood supply chain is considered concurrently with decisions on how to extract the product without causing harm to the supplier.

The principle reason underlying the development of the conceptual framework was the desire to integrate recent conceptual advances from multiple disciplines in the pursuit of developing a novel and practical approach to exploring seafood sustainability. Through such an approach it was hoped that the conceptual framework presented in Figure 56 would be intuitive and accessible to researchers and managers from multiple disciplines, ranging from marine ecologists and social scientists, to business management researchers.

One challenge for exploring sustainability in habitat mediated fishery supply chains is that production occurs irrespective of consumer demand, and such production is often highly variable. For this reason, thus SSCM initiatives are more about manipulating demand to suit constrained and unpredictable supply, rather than stimulating or suppressing demand for products to stimulate or suppress production.

In much of the conventional fisheries research to date, the 'supply chain' is often considered from either side of the industry, which is considered as something of a 'black box' – e.g which a unit that can be viewed in terms of its inputs and outputs (or transfer characteristics), without any knowledge of its internal workings. For example, ecologists, or environmental economists might consider the ecological system and 'production' in detail – but consider seafood demand us just an aggregate figure. Whereas those looking from a conventional supply chain management, marketing or economics perspective, might just consider supply as an aggregate figure without much understanding of the below surface (production) processes.

The unique contribution of the proposed conceptual framework is an examination of the whole supply chain looking in detail at both below the surface (ecological system) and above the surface (socio-economic system) processes (Figure 191). Through adopting a multidisciplinary approach to the framework has also helped to draw on the inherent strengths of monodisciplinary research, combining these strengths to provide a richer picture of the complexities surrounding SSCF seafood supply chains, and thus help identify some of the supply-side characteristics and drivers of demand that exist in seafood supply chains.

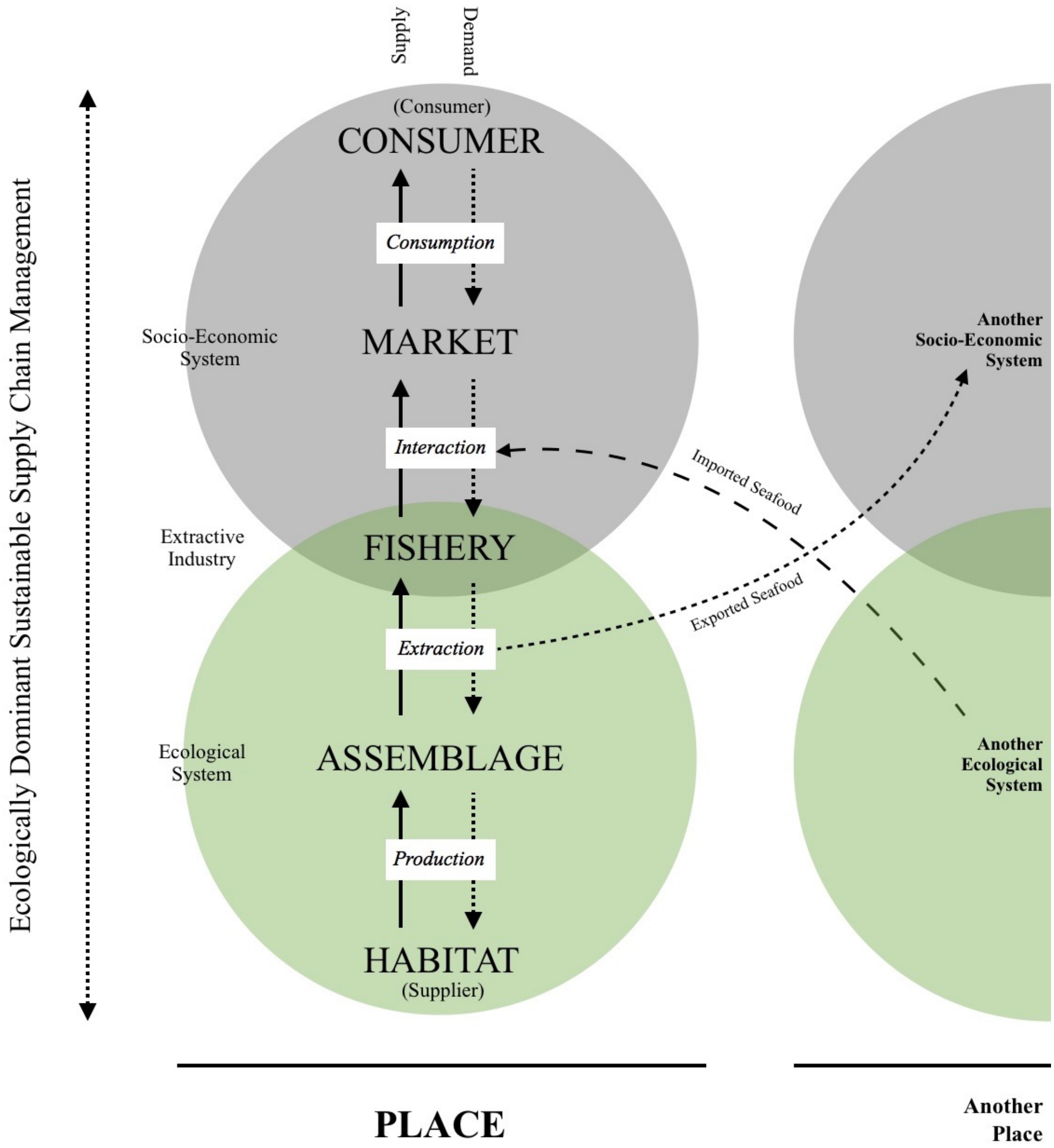

Figure 167. The Ecologically Dominant, Small-Scale Capture Fishery, Sustainable Supply Chain Management, Conceptual Framework showing the Habitat as the supplier in any given place. Sustainable Supply Chain Management occurs throughout the supply chain and decision making is performed from an Economically Dominant perspective, whereby decisions are made that favour perpetuity of seafood supply over meeting immediate seafood demand. The whole process is considered within pre-defined parameters of 'place'. The extractive industry (the FISHERY) occurs at the confluence of the socio-economic and ecological systems. This seafood supply chain interacts with others, in different places, via the import and export of seafood products.

10.2 Synopsis

In this section a synopsis of this thesis's findings is provided, drawing together each research chapters' *key findings* to "tell the story" of the Lipsi SSCF seafood supply chain. In Chapter 4, the SSCF Conceptual Framework was outlined, this was followed by the results chapters; 5 to 9 in which each of the five supply chain stages were interrogated:

Stage 1 – Chapter 5 focussed on habitats of place, as the suppliers of products to the SSCF. This chapter defined the coastal habitat types, recorded their relative size and distribution, and characterised their health by documenting their physical characteristics.

(a - Production)

Stage 2 – Chapter 6 focussed on the species assemblages as the reservoir of seafood products from which SSCF extraction takes place. Here the seafood products that exist in the coastal habitats were defined and their association to one or multiple habitats recorded. The trophic level and size of individuals caught were documented to contextualise the food web.

(b - Extraction)

Stage 3 – Chapter 7 focussed on the SSCF fishery as the extractive industry. The fishery was defined by what, where and how it is fished and by what seafood products were being extracted from each habitat. This was contextualised through exploration of temporal trends witnessed by participants in the industry.

(c - Interaction)

Stage 4 – Chapter 8 focussed on the marketplace, and the choice architecture presented to seafood consumers. Here the seafood supply chains available to the consumers were characterised, the seafood products presented at market documented and way seafood products are presented to the consumer defined.

(d - Consumption)

Stage 5 – Chapter 9 focussed on the consumers, as the origin of demand for seafood products on Lipsi. Here the relative demand for products was explored by characterising the different social drivers of demand, and through exploring the influence of consumer demographics on consumers purchasing power.

Each of the five stages are linked by the dynamic processes that link the individual stages of the supply chain, including the '*production*' of the seafood product, the '*extraction*' of the seafood product, the '*interaction*' of the seafood product at market (with competing products from other supply chains) before the final '*consumption*' of the seafood product via purchase by the end consumer.

A segmented synopsis of the overall thesis findings follows, summarising the results from each of the five stages (1-5), and the linked processes (a-d) that exist between them.

Stage 1 - Habitat

For the Lipsi SSCF, the seascape in which the seafood is *produced*, and from which it is *extracted*, are characterised by several interconnect habitats which all have different contributions to make with regards to the diversity and abundance of seafood products that are supplied to Stage 2, the species assemblage.

Outreach to Traditional and Local Ecological Knowledge

Of the 150km^2 of 'place' considered in this thesis, approximately 132.6km^2 constituted 'seascape', with 'landscape' on the Island of Lipsi accounting for just 17.4km^2. Outreach to Local Ecological Knowledge (LEK) enabled the broad characterisation of seascape habitats, with ≈ 71.8km^2 of habitats reported. This constituted an estimated ≈11.6km^2 of un-vegetated sandy bottom, ≈23.6km^2 of rocky-algal habitat, ≈24.3km^2 of seagrass meadows and ≈12.3km^2 of Coralline reefs. Unreported habitat types represented ≈ 60.8km^2. At this scale (km^2), such broad habitat descriptions are useful indicators of broad seascape productivity and this seafood product supply. Documenting the reported locations of productive habitats (supply hotspots) should help to facilitate local scale protection of these habitats.

Aerial Remote Sensing using an Unmanned Aerial Vehicle

Following this, and to get a more detailed understanding of habitat mediated seafood supply, nine bays were selected around Lipsi for UAV facilitated habitat mapping at the site scale (m^2). Using an UAV, a total area of 121,886m^2 (12.19ha) was mapped across the 9 sites, allowing for habitat and site characterisation at the scale of 4.75cm^2 per pixel. A total of 34,128m^2 (3,41ha) of seagrass, 30,652m^2 (3,07ha) and 57,106m^2 (5,71ha) of sand was mapped across each of the nine sites, illustrating the 9 sites habitat heterogeneity and the need for accurate habitats maps. This multi-scale approach enabled quantitative data at the m^2 scale to inform habitat descriptions at the km^2 scale. It also enabled created context for both the in-situ observations of habitat, and for the species assemblage studies of Stage 2.

In-situ Observations using Seagrass-Watch methods

Finally, *in-situ,* patch scale (mm) observations of habitat enabled a richer understanding of habitat characteristics (complexity, integrity, health) by using established Seagrass-Watch protocols. Here physical variables pertaining to seagrass physiology were measured e.g. seagrass canopy height, seagrass percent cover, epiphyte cover and algae cover. These variables illustrated the seasonal nature of *Posidonia oceanica* seagrass meadows (via significant changes in canopy height) and highlight the site-specific degradation of meadows linked to various anthropogenic effects (e.g. eutrophication in Moschato, anchor damage in Papadria) which can help inform site scale management of these habitats.

Link (a) – Production

At the origin of the Lipsi SSCF supply chain are the habitats (suppliers) which support the production of SSCF seafood products. In such a seafood ‘goods market’, the ‘production’ is the amount, and the type of seafood product created per unit time (when all other factors are held constant). The ecological reality, for the Lipsi SSCF, is therefore that the supply and availability of seafood products is mediated by how that habitat is affected by the time of year (season), by the extent (size and distribution) and by the integrity (health) of the provisioning coastal habitats. (NB – If the species assemblage is degraded this will also affect product supply. This is covered below in Stage 2).

For SSCM of the Lipsi SSCF, this knowledge is crucial: If degradation of the identified coastal habitats occur, then the variety and the volume of seafood products supplied can be expected to reduce in a predictable manner. For example, Lipsi's estimated 24.3km^2 of coastal seagrass meadows currently offer 39 more species to the supply chain than would degraded (proxy – sandy bottom) habitats, and up to 2.5 times the catch provision. Or, if the current small area (12.3km^2) of coralligène reefs were to be degraded, then whilst the loss of species diversity would be less (the habitat offers just 8 more species), the species that are currently caught are done so at volumes up to 4.1 times greater than the adjacent sand habitats and thus loss of this reef would lead to a marked reduction of product supply entering the SSCF supply chain.

Stage 2 - Assemblage

The faunal assemblage refers to all the various animal species that exist within a habitat. However, whilst not all species that exist in an assemblage will be extracted (b), the diversity and abundance of species present in each habitat act as key indicators of that habitat's productivity. For example, if the abundance of species recorded is below that of the carrying capacity for the habitat, or if the diversity / size of species is indicative of a degraded and unstable food web, then this can inform the SSCM of the Lipsi fishery. Broadly speaking, the SSCM of the SSCF will focus on sustaining the *production* of seafood products from those habitats that supply the greatest diversity and abundance of species.

Underwater Visual Census

A combined 144hrs of UVCs were conducted which revealed that, compared to a baseline of sand (the least productive habitat studied), rocky-algal habitats supported 20.0% greater species diversity with individual abundances 4.4 times higher (range: APC 5.0 – AST 3.7 times higher) than un-vegetated sandy bottom. Seagrass meadows were even more productive with 31.6% more species recorded in them, and individual abundances 5.4 times higher (range: APC 6.5 – AST 4.2 times higher) than bare sand.

Baited Remote Underwater Video

A combined 432hrs of BRUV video was analysed which revealed that, compared to a baseline of sand (the least productive habitat studied), rocky-algal habitats supported 6.8% greater species diversity, with individual abundances 2.8 times higher than un-vegetated sandy bottom. Seagrass meadows were even more productive with 31.8% more species recorded in them, and individual abundances 1.7 times higher than bare sand.

Catch and Release Nets

A combined 9720hrs of fishing effort by Catch and Release nets revealed that, compared to a baseline of sand (the least productive habitat studied), rocky-algal habitats supported 15.4% greater species diversity, with individual abundances 1.9 (Range: Fyke 1.3 – AST 2.6 times higher) times higher than un-vegetated sandy bottom. Seagrass meadows were even more productive with 107.7% more species recorded in them, and individual abundances 3.1 times higher (Range: Fyke 2.8 – Minnow 3.7 times higher) than bare sand.

Notably, 96.6% of individuals recorded by Underwater Visual Census and 59.7% of individuals recorded by the Catch and Release Nets were juveniles. This suggests both a strong 'nursery' role for the habitats of the shallow coastal zone. In addition, 98.9% of the 'Top 20' most frequently recorded species were principal fishery species, showing a very strong link between those species being *produced* by the coastal habitats and those that are *extracted* by the Lipsi small-scale capture fishery.

Link (b) – Extraction

Linking the assemblage with the fishery in the seafood supply chain is the process of extraction. Whilst, the habitats supply a variety of seafood products to the assemblage, it is up to the fishery to determine the rates and methods (and thus sustainability) of extraction. This process entails the complete the ecological system.

Similar to ‘production’ (outlined above), the ‘extraction’ is the amount, and the type of seafood product removed per unit time (when all other factors are held constant). For the fishery, the seafood supply, and capacity to extract seafood products is mediated by the weather (physical capacity to fish), by the methods used (gear choice) and by the socio-economic context of place (often the right to fish). For SSCM of the Lipsi SSCF understanding the nature of extraction is crucial: If degradation of species assemblages occur during the extraction process, then the variety and the volume of seafood products supplied can be expected to reduce in a predictable manner.

For example, the data showed that the Red Porgy (*Pagrus pagrus*) was being landed below the length at maturity. In these instances, the individuals would not have had the opportunity to reproduce, threatening the perpetuity of the species and thus future seafood supply.

Stage 3 – Fishery

The Lipsi Fishery sits at the centre of this supply chain research, straddling both the socio-economic and ecological systems. Daily decisions made by SSCF fishers on what species to target for extraction, and when to target them are directly influenced ‘from above’ by the interacting socio-economics of ‘Consumer’ demand and ‘Market’ choice, whilst being influenced ‘from below’ by the ecological realities of ‘Habitat’ seafood provision and therefore species ‘Assemblage’ composition.
For the Lipsi SSCF, the daily decision of how, where and when to fish on any given day comes down to the twin supply chain influencers of supply and demand. For example, the influx of tourists over the summer (Jun-Aug) creates a seasonal demand for local seafood extraction that isn’t demanded outside of this season. However, these summer months are also the critical period for the growth and development of juvenile fish assemblages, and thus, an existing SSCM measure exists to protect habitat mediated seafood provision during this period (a closed season for Greek trawlers from the 1st of June to the 30th of September). However, this existing SSCM decision (whilst designed to protect future seafood provision)

reduces the overall supply of fresh fish to market during the summer months, and thus places the onus of provision on the SSCF, on aquaculture and on seafood imports.

SSCF fishers thus face the dilemma of trying to meet the spike in demand for seafood products from consumers at a time when stocks are trying to be protected for the sake of future provision and stock 'sustainability'.

Reported Fisheries Data

The Lipsi SSCF is the principal extractive actor in the seafood supply chain, with 10 full-time fishermen and a further 15 part-time vessels extracting species from the coastal habitats. All fishing occurs from small-scale fishing vessels (<12m in length), with 73% of fishing occurring coastally in the 0-25m depth range. Fishing was principally conducted using Trammel nets (63%) and Gill nets (23%) targeting both seagrass (53%) and Rocky-algal (29%) habitats. Extracted species diversity and abundance was highest in Spring and lowest in Autumn with a marked change in gear choice in September from trammel and gill nets (characteristic of the Spring and Summer), to Handlines and Longlines (characteristic of the Autumn). No data for the limited Winter fishery is available. Critically, landings data revealed that seagrass meadows offered fishers the highest diversity of species, followed by rocky-algal and then coralligène reefs. However, it was coralligène reefs that offered the highest abundance of individuals followed by seagrass meadows and then rocky-algal habits. Sand offered the least diversity and abundance of species.

Fisheries Landings Data

69 seafood products were recorded from extraction data of the SSCF. The 10 most common products accounted for 85.2% of all seafood products extracted, and the 30 most common seafood products accounted for 96.7% of all extractions. The copius supply of the most abundant seafood products, for example the Dusky Spinefoot (*Siganus luridus*) more than meets the demand for the product in the marketplace. In contrast however, the market supply of the Common seabream (*Pagrus pagrus*), the Gilthead seabream (*Sparus aurata*) and the Common dentex (*Dentex dentex)* do not meet demand. Critically, for SSCM, the most abundant species were seasonally supplied most often from the more 'complex' habitat types. Specifically, the

coralligène reefs, at depths beyond 50m, during the Autumn (e.g. *Dentex marcropthalmus, Pagellus erythrinus*) and the seagrass meadows and rocky-algal formations, at depths below 50m, in the Spring and Summer (e.g. *Signaus luridus*, *Oblada melanua, Sparisoma cretense, Scorpaena scrofa*).

Fisheries Ecological Knowledge

Without baseline data to compare to it is challenging to determine whether extraction rates are too high for the sustainability of the fishery. However, the temporal changes reported in the decline in the abundance of fish since the early 1990s suggests that extraction rates are currently too high to sustain. Much of the blame is assigned to the large-scale fishery, and particularly the trawlers that have allegedly degraded the marine habitats, reducing product supply.

Link (c) – Interaction

Understanding the complexities of the marketplace, specifically the interaction of seafood products that originate from multiple seafood supply chains, provides a richer picture to inform SSCM decision making. Whilst in artisanal fisheries, it is not uncommon for fishers to be involved directly in the retail process with the end consumer, in more formal marketplaces, supply chains can consist of several mid-chain links, here collectively represented as 'market', which can include seafood aggregators, primary processors, secondary processors, traders, wholesalers and distributors who will transform, package and move seafood products from their location of extraction, to the location of the final sale.

In this study by defining 'place' at an appropriate socio-economic scale (i.e. the northern Dodecanese) it has been possible to contextualise seafood extraction from the ecological system (i.e. the Lipsi seascape) without 'falling into the trap' of assuming the physical seafood retailers of Lipsi appropriately represents the only 'market' for seafood for local consumers. Whilst consumers on Lipsi can, and do, purchase seafood on Lipsi, they can, and do, purchase seafood from the immediately adjacent islands if desired (in much the same manner that individuals in Britain may travel to larger commercial centres e.g. Edinburgh, Cardiff, or London to purchase particular goods or services).

By documenting the 'supermarketisation' of adjacent islands it helps to contextualise where the Lipsi SSCF seafood supply chain is positioned in the Marketplace, and thus how the fresh seafood products supplied are likely to interact with others products, originating from other seafood supply chains, that offer choice to the Lipsi consumer at the 'Market' stage.

Stage 4 – Market

A total of 69 species were landed by the Lipsi SSCF, representing 45.1% of the total of 153 species which were recorded for sale in the marketplace. A further 21 species of Mediterranean origin were also recorded for sale in the Marketplace (contributions from aquaculture and the large-scale fishery supply chains) meaning that for the consumer 58.8% of seafood species available in the marketplace were of Mediterranean origin (n=90). The remaining 41.2% (53 species) were imported species from 41 countries (representing global supply chains) with species origins from habitats originating in the Indian (20 species), Atlantic (31 species) and Pacific (33 species) oceans.

Market Infrastructure
The capacity for seafood product choice increases with the size and infrastructure of the island, with the supermarketisation of larger islands facilitating international seafood supply chains to deliver imported seafood products to the consumer. Supermarketisation of the northern Dodecanese has meant that Consumers on Lipsi have access to seafood products that are unavailable from the SSCF, in particular including Salmon (Salmonidae), Prawns (Penaeidae), Cod (Gadidae) and Mussels (Mytilidae).

Product Availability

To the Lipsi consumer seafood products were recorded in the northern Dodecanese archipelago from every major fishing area outside of the Arctic (Major Fishing Area 18) and the Antarctic (Major Fishing Areas 48, 58, and 88) illustrating the truly global nature of seafood supply chains (Figure 167). Seven of the species recorded are amongst the top 10 species by capture production globally, and form a major component of internationally traded seafood products (FAO, 2014).

Product Presentation

On Lipsi, 'fresh' seafood products are most abundant, but are limited to those caught by the SSCF, especially during peak tourist season when the large scale (trawl and seine) fishery is closed across Greece. This represents approximately 6 times more choice than tinned and a little over 8.5 times more choice than frozen produce. However, frozen and tinned products offer the consumer the option for consumption of species that are unavailable locally and thus are competing with the locally sourced SSCF products in the Marketplace.

Link (d) – Consumption

Understanding the *consumption* patterns of seafood products is an essential component of informed SSCM. A principal reason for adopting this perspective is it enables us to articulate and explore those consumer characteristics that could produce differential demand in the supply chain.

For example, it was elicited here through Visitor Exit Survey that tourists to Lipsi were creating a demand for a different suite of seafood products (Prawns, Salmon and Mussels) that cannot be obtained from traditional, local, small-scale capture fishery supply chains (they are produced in other places). It also enables researchers and managers to explore the different 'socio-economic value' that local consumers assign to different marine species i.e. ranging from just €2/kg for the abundant and invasive Rabbitfish (Siganidae) to €25/kg for Groupers (Serranidae) or as much as €35/kg for the rarer Lobsters (Palinuridae / Scyllaridae).

Such knowledge can enable socio-economically informed SSCM decisions to be made in line with ecological knowledge, rather than making SCM decisions made for the ecological system in isolation.

Stage 5 - Consumer

The demand for seafood products in the supply chain originates with the end consumer. Here, trends in consumer demographics can be linked to patterns of *consumption* and the demand for certain seafood products. This demand, in turn, drives the extraction of popular species in the seafood supply chains, be they global, or local.

Resident Household Surveys

123 surveys conducted with island households reported that the primary source for obtaining seafood on the island was from the small-scale fishing fleet (91.1%), with roughly one quarter of households surveyed were directly involved in the capture process (27.6%) and (75.6%) sourcing fresh fish directly from the fishermen. Greek nationals inhabited 90.2% of the households surveyed and therefore there a largely uniform demographic regarding to traditional social and cultural norms.

Visitor Exit Surveys

In contrast, 723 Visitor Exit Surveys conducted with tourists revealed 27 nationalities, of which 25.5% were Italian, 14.5% English, 12.2% German and 9.4% French. Included in the remaining 30.9% of tourists were just 7.5% domestic Greek tourists suggesting over 9 in 10 visitors would be bringing with them social and cultural norms relating to food consumption from abroad. Tourists primarily sourced their seafood from restaurants (77.0%) with just 23 respondents (3.2%) reporting purchasing seafood directly from the local fishermen illustrating a marked contrast in seafood consumption patterns between the local people and tourist groups.

Economic Survey

The final element of this component was an economic survey and valuation (€/kg) of landed SSCF species. Here the Top 3 families popular with local consumer; the Mediterranean parrotfish (*Sparisoma cretense*), the Comber (*Serranus cabrilla*) the Dusky spinefoot (*Siganus luridus*) were substantially cheaper (€7-10/kg, €4-6/kg and €2-4/kg respectively) than those species of Ocotopodidae (€5-10/kg) Penaeidae (no data - imported) and Sparidae (principally *Sparus aurata*) €20-22/kg. This makes sense considering the relative low 'purchasing power' of Greek nationals when compared to the national average of the nationals from the dominant tourist nations e.g. Germany, Australia, USA etc.

Although we commonly call it a supply "chain" there are few products in today's globalised economy that move along a simple, linear track, from production to consumption. Despite that, the concept is intuitive and intelligible across the research and management spectrum.

In this thesis, a conceptualised SSCF supply chain is presented that represents the process of getting a seafood product (a marine species) from the producer (the habitat) to the consumer; moving beyond the traditional (place-less) "catch to market" supply chains to consider the place of extraction and the habitats associated with seafood product provision (Figure 192).

The strength of articulating this process via the supply chain model is that it allows emphasis to be placed on the key processes e.g. (production, extraction, interaction and consumption) that form the links between the key supply chains stages (habitat, assemblage, fishery, market and consumer). Through this medium it is thus possible to track a product's life history from location of production to its eventual consumption (for example FollowFish.de).

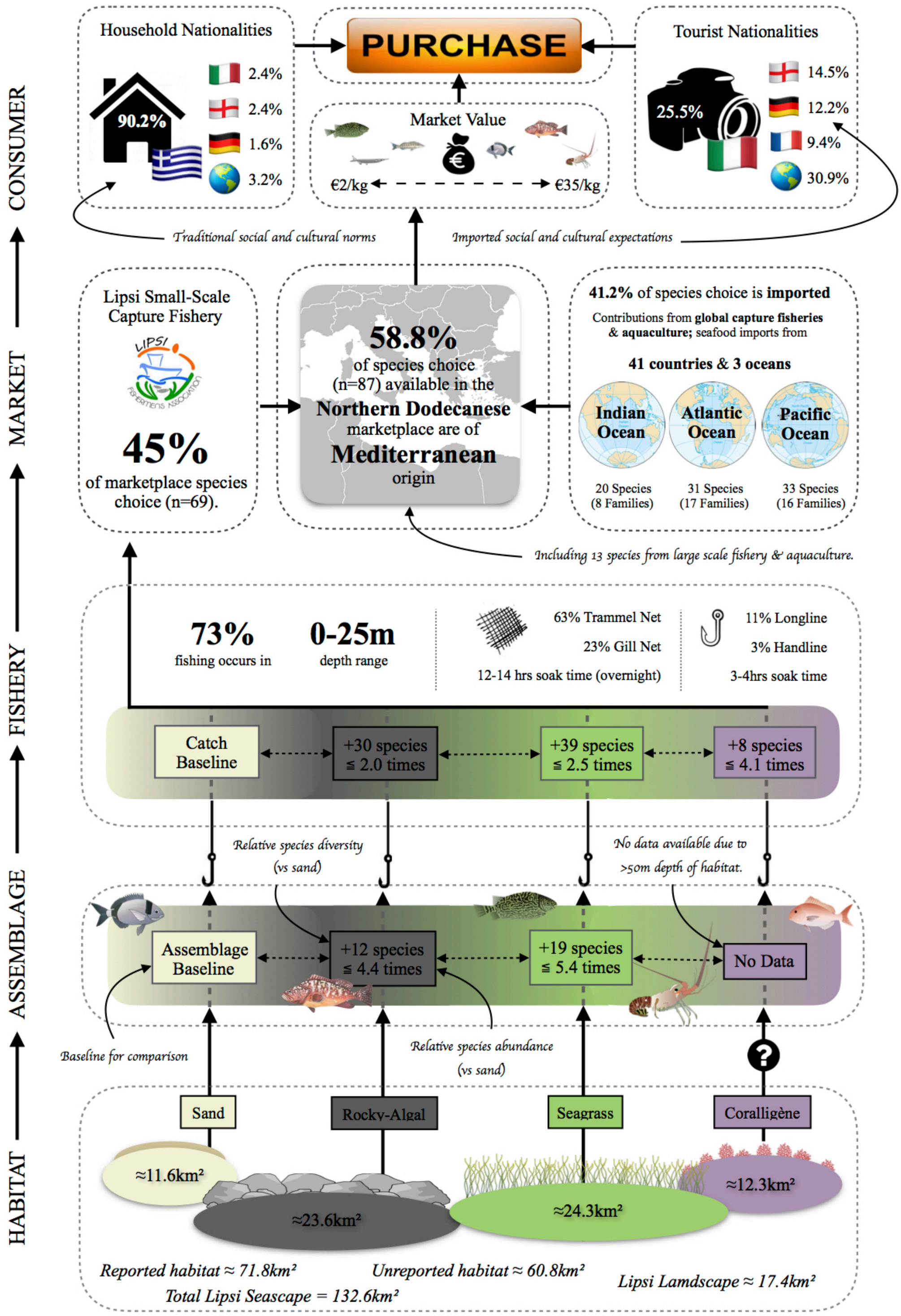

Figure 168. An infographic illustrating how the Lipsi Small-Scale Capture Fishery is dependent upon the provision of seafood from various habitats (the suppliers) across the Lipsi seascape, with some suppliers provisioning more than others.

10.3 Conclusions relating to major aspects explored.

Place-based Research

The first stage in interrogating the Lipsi SSCF seafood supply chain was thus in defining the parameters of 'place' (Figure 193); both *ecologically* (where the fish are extracted) and *socio-economically* (where the seafood is purchased). Here 'place' was defined *ecologically* as the ≈150km^2 of coastal waters surrounding the island of Lipsi and *socio-economically* as the immediately adjacent island communities of the northern Dodecanese from where people from Lipsi can purchase seafood.

Figure 169. A figure illustrating the place-based nature of Small-Scale Capture Fisheries. At one end of the spectrum, a farm offers a supply chain rooted in place, at the other end of the spectrum, high seas pelagic fishing involves extraction in an almost placeless environment. Small-Scale Capture Fisheries are often intrinsically linked to the productivity of place.

One of the key-factors leading to the over-extraction of marine resources is poor stock assessment techniques that do not account for the spatial and temporal variations in marine product supply (Halpern et al., 2008). Here, estimates of fish abundance based upon 'generic' seascape areas will not accurately reflect the heterogeneity of habitat seafood provision. This risks a bias towards calculating extractive rates based upon places that are more productive than elsewhere in the seascape, leading to over-estimates of the amount of available seafood. Such inaccuracies can then lead to over-extraction of marine resources in place, because (in the absence of more reliable information) stock managers become over-optimistic about the resource (Burgman and Lindenmayer, 2005). Indeed, failure to incorporate spatial patterns of supply impairs management of marine ecosystems and their associated fisheries (Wilen, 2004).

In the terrestrial realm, suggestions are being proposed for the inclusion of a formal assessment of the risk of ecosystem collapse (see Burns et al., 2015). Here assessments are to be based upon rates of species extraction, and the interaction of species extraction with other factors, such as climate change or the invasions of exotic species. Concurrent to this development, the International Union for Conservation of Nature (IUCN) has also been developing a formal protocol for assessing the status of ecosystems (see Keith et al., 2013) which is proposed to be similar to their traditional approach to assessing the conservation status of individual species (e.g. as Critically Endangered (CR) Endangered (EN), Vulnerable (VU) of Least Concern (LC)). Critically for fisheries, what both developments point to is the need to better understand place-based fish species demands, specifically ensuring that they are better monitored, including mapping of where particular stocks occur (habitat) and in what condition (assemblage) (Lindenmayer et al., 2005).

Ecologically Dominant Logic Sustainable Supply Chain Management

Recent developments in SSCM thinking are helping to restructure the narrative towards the resilience of ecological systems on which socio-economic supply chains depend (Seuring, 2013, Stadtler, 2015). This ties into the decision-making process surrounding management decisions that affect the supply chain; by using an Ecologically Dominant logic to make the decisions the management of the supply chain is made sustainable.

An Ecologically Dominant framework moves the field of SSCM away from the question of how can fishery supply chains can merely diminish environmental or social problems, to the root question of how seafood supply chains can truly become sustainable (*sensu* Montabon et al, 2016). Under this proposed conceptual framework, the various habitats act as the conventional ‘suppliers’ to the supply chain, thus any degradation or damage to the habitats will also degrade seafood supply and thus have knock-on effects further up the supply chain.

Seafood Supply Chains

Per the FAO (2014), on a global scale, each year, seafood supply chains account for approximately 158 million metric tons of product (of which around 91 million tons are from capture fisheries). Tens of millions of people globally are involved in an industry that extract thousands of species from the seas and oceans right across the planet. The industry exists at scales from the artisanal, to the industrial, and from the place-based (Young et al, 2007) to the placeless (Bush et al, 2015). In addition, certain product characteristics as well as the practices of supply chain actors make seafood supply a wholly unique industry.

As aforementioned, seafood supply chains, like some other natural resource supply chains are unique in that that production occurs irrespective of consumer demand. Seafood supply chains face the additional challenge that their production is also often highly variable. Whilst other natural resource industries e.g. forestry will also experience production without demand, the SSCM of forestry products is made easier by the relatively predictable 'maturation' and 'turn over', they are often within clearer boundaries of ownership, rather than facing the 'tragedy of the commons', and principally, they are easier to manage since the products don't move!

With a few exceptions, the current structure and culture of international seafood supply chains make it practically impossible for **Consumers** to distinguish at **Market** the sustainably harvested products from unsustainably harvested ones. Unfortunately, this is true in some cases even in fisheries that have been 'certified sustainable' (Marko et al., 2011). This means that even if SSCM initiatives (such as MSC fisheries) that target *consumption* is implemented, there is no guarantee that such management initiatives with result in true extractive sustainability. In Marko et al's (2011) example, species identification data was lost (or a product) deliberately mislabelled between the **Fishery** and the **Market,** and thus the challenge for product traceability lies at the point at which product processing and *interaction* occurs, between different species, and those that are brought to market from several seafood supply chains.

Critical too, is the data collection needed for monitoring *extraction* of species from the **Assemblage**, and thus the need to provide traceability beyond traditional "catch to market" supply chains. Quantitative data collection must start with the *production* of the seafood in the **Habitat** to provide a context for *extraction* from the

Assemblage. Indeed, given the fractured and convoluted nature of seafood supply chains it is;

"impossible to gauge what is happening in a data-deficient fishery by attempting to trace product back from the end buyer [Consumer] *to the resource* [Habitat]*"*

Future Of Fish, 2015

However, by starting with the resource (with the **Habitat)**, and following the product up the supply chain, it is possible to begin to build knowledge of those resources involved in seafood *production,* and thus which **Assemblages** can be targets for *extraction* by the **Fishery**. Knowing the place of origin of the product it is then the responsibility of the retailers to prepare the product for *interaction* with others at **Market** so that informed decisions regarding seafood product *consumption* can be made by the end **Consumer**.

Through adopting this conceptual framework, it is possible for supply chain managers and researchers to articulate, design and execute place-appropriate initiatives and engagements using a common framework. It has been shown in this thesis that by adopting such an approach will take SSCM beyond "Catch to Market" and make seafood sustainability in SSCF truly a "Habitat to Consumer" consideration.

The Mediterranean

There is a widespread interest in securing sustainable small-scale fisheries in the Mediterranean and Black Sea (FAO, 2016), consistent with the FAO Code of Conduct for Responsible Fisheries (1995). This is especially important in the Mediterranean and Black Sea since small-scale fisheries in the Mediterranean and the Black sea have been acknowledged as the main fishing sector providing food supply and livelihood in both regions: Roughly 80 percent of the fisheries are small-scale in terms of fishing units (FAO, 2016).

Against a global backdrop of declining fish catches in the order of 1.2 million metric tons per year since 1996 (Pauly and Zeller, 2016) this is of immediate concern. The declining catch has resulted in lower per capita seafood availability, and it has been recently predicted that 11% of the global population could face micronutrient and fatty-acid deficiencies driven by fish decline over the coming decades, resulting in around 845 million people living with extremely low levels of Iron, Zinc or Vitamin A (Golden et al, 2016).

It has been publically acknowledged (FAO, 2016), that to provide a full picture of small-scale fisheries in the Mediterranean and the Black Sea, comprehensive information should be collected which improves our knowledge on small-scale fisheries will help in defining strategies to address the sector in terms of management, monitoring and sustainable development actions.

The Ecologically Dominant Small-Scale Capture Fisheries Conceptual Framework presented here represents a potential collaborative platform for facilitating Sustainable Supply Chain Management initiatives that consider the seafood supply chain from the point of *production,* to the point of *consumption* i.e. from "Habitat to Consumer".

Place-based research using this framework could identify 'hotspots' that urgently need more effective strategies for fisheries conservation, and sustainable supply chain management; '*to rebuild stocks for nutritional security'* (Pauly and Zeller, 2016). A holistic approach is required that captures both the ecological and the socio-economic, since, for example, data on food-price fluctuations are needed (see Golden et al, 2016) so that models of fish supply and dietary substitution can be conducted.

A recent meta-analysis of nearly 5,000 fisheries found that applying sound management reforms to global fisheries could increase catch by more than 10% (Costello et al., 2016) and yet application of management reforms will be difficult to achieve unless fishers, managers and government can articulate management initiatives using a common conceptual framework. The provision of this Ecologically Dominant SSCF SSCM framework can act as the framework which brings together these disparate stakeholder groups.

The Fishing Industry

Industries based on the extraction of natural resources have often attracted substantial controversy, and frequently these industries have been socially, economically and environmentally divisive (e.g. Larkin, 1977; Mansfield, 2011). One of the most controversial extractive industries worldwide are fisheries (Pauly and MacLean, 2003; Costello et al., 2016), which historically have been plagued by resource over-commitment (Larkin, 1977). As such, a large proportion of current stocks are heavily over-exploited and poorly managed (Costello et al., 2016; Pauly and MacLean, 2003).

Globally, the problems of fisheries resource over-extraction and the associated potential for ecosystem (and thus supply chain) collapse, are inherently ones that have been derived from the challenges surrounding the governance and policing of a common resource. Even so, lack of, or poor resource management decisions are generally influenced by demand originating in the socio-economic system, and can be linked to economic, political and labour market power (Lindenmayer, 2016).

For example, the problem of marine resource over-extraction has been linked to institutional 'gambling' in which the level of stock availability and associated levels of direct employment are deliberately over-stated e.g. China's over-reporting skewing global fisheries data (see Pauly and Watson, 2003). This may be to secure the status and influence of a given institution with government or for other reasons, such as leverage in negotiations over access to resources. (Lindenmayer, 2016)

The over-extraction of marine resources in any given place, can manifest itself in several ways, and be compounded by other local problems. However, across places, if extraction is to be sustainable, the principle rule is that the rate of seafood extraction is set at a level in which for those marine resources that are harvested, more marine resources are supplied (per unit time), thus avoiding both stock depletion and the erosion on 'non-target' resources (Árnason et al., 2009)

Precautionary approach and ecological margins

A second key factor leading to the over extraction of marine resources is that often target fishing quotas do not make provision for the loss of marine resources that result from stochastic natural events (e.g. heatwaves or cyclones) that can disrupt seafood supply. In fact, such 'buffers' sit directly at odds with the need to make supply chains as efficient as possible and maximise supply chain profitability and performance (Gunasekaran et al., 2004). Indeed, there may be several other factors that may not directly relate to supply chain performance that will impinge on resource extraction. For example, in the case of the Lipsi fishery, the need to protect threatened species such as the Mediterranean Monk Seal (*Monachus monahcus*) (see Rios et al., 2017).

Failure to account for either stochasticity or such other factors means that the estimates of what constitutes a sustainable rate of extraction do not have sufficient 'ecological margin' to accommodate these impacts on the seafood available for extraction (Lindenmayer, 2016). For this reason, more 'robust' and 'realistic' stock assessments have been called for that include quantification of levels of uncertainty in the size and spatial and temporal variability in stocks. This is crucial as it has long been recognised that over-commitment of resources lies at the heart of unsustainable extraction practices that ultimately become uneconomic harvesting practices (Talbot, 1993; Pauly and MacLean, 2003).

Transparency and political power

Greek fisheries suffer from the issue that key policy and management decisions about the amount, type and location of marine extraction are heavily influenced by people and institutions with economic power and vested interests e.g. the 'Panhellenic Middle Range Union of Shipowners' which represents the large-scale fishery (trawlers and purse-seiners) and the production of 85% of fishing products (Europa, 2012). The management of marine resources is also driven by historical norms and decisions made in the past that have placed certain individuals or representatives of organised labour in a position of power e.g. fishing unions, professional organisations or certain government agencies, and companies.

"Everyone protects their interests but those with power have the ability to enact or resist change to further their own positions"

Lindenmayer, 2016

Economic and political power is the fundamental driver of the demand for extraction discussed in this thesis, and any solution or set of solutions to bring sustainability to the SSCF supply chain will fall short unless it engages with these socio-economic drivers of extraction.

10.4 Practical Contributions of the Thesis

This thesis has identified a number of potential 'Supply-Side' and 'Demand-Side' intitiatives that could be pursued in order to improve the likelihood of longer term supply chain sustainability goals being met.

There are five Supply-Side initiatives that are articulated here, and three Demand-Side initiatives. These initiatives are not supposed to be an exhaustive list but are presented as a recommended suite of SSCM initiatives that would, based on the research presented here, likely engender a positive contribution towards to seafood supply chain sustainability. Some of the suggestions presented here are easier to achieve than others, and some may well require further research before they can be realised.

The 'Supply-Side' initiatives look to improve the quality and quantitiy of seafood products available to the fishery by addressing 'Habitat' and 'Assemblage' challenges. 'Demand-Side' initiatives look to shift the patterns of seafood exploitation by offering recommendations that address the social, economic and cultural drivers of extraction, including 'Marketplace' and 'Consumer' elements. In both cases, the recommendations seek to 'nudge' (or even 'shift'!) the seafood Small-Scale Capture Fishery seafood supply chain towards a sustainable trajectory.

It must be stated here that the success, or otherwise, of these recommendations will depend on both the communities desire to see them realised, and the power and economic structures that are currently in place on Lipsi wishing to support the community to make these changes. In some cases, further scientific research may also be needed.

10.4.1 Supply-Side Initiatives

Management Initiative 1 = *Trash removal and surface dredging at Moschato.*

Supply Chain Risk: At present the bay of Moschato is full of sediment and marine litter. During the prolonged periods of etesian winds ("Meltemi") the bay is subject to windswell originating from the north-west, which enters the bay, re-suspending sediment. This reduces water clarity and will hinder growth of *Posidonia oceanica* seagrass.

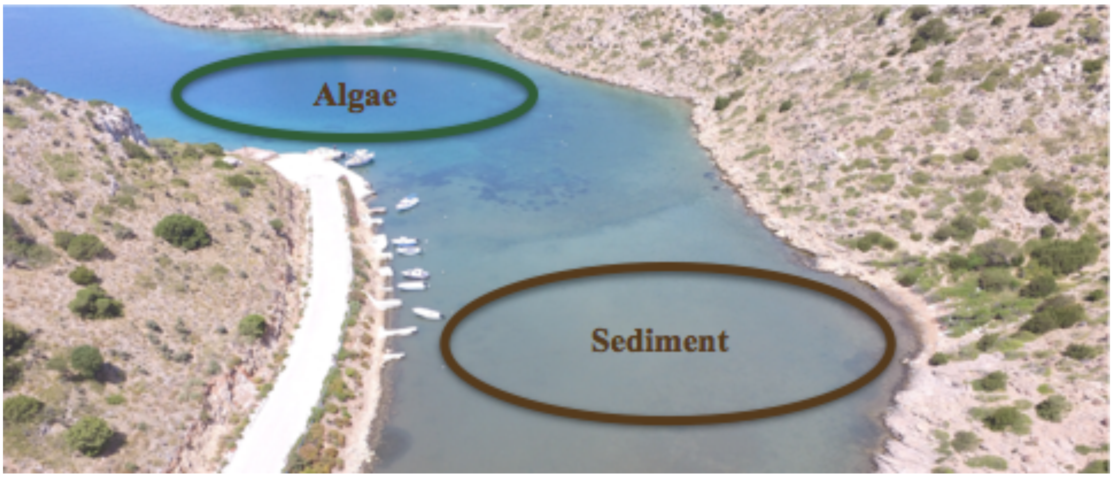

Figure 170 - An aerial view of Moschato Bay on Lipsi. The bay was previously covered in *P.oceanica* seagrass but has over the past 30 years transitioned into a bay dominated by algae and sediment.

Management Opportunity: If there are any plans for the further development of the port (Figure 1), this should be realised in the near future so that the sediment, algae and litter can be removed from the bay and the bay restored with productive juvenile habitat. This habitat could take the form of transplated seagrasses; *Posdionia oceanica* or *Cymodocea nodosea,* and/or artificial reefs as appropriate.

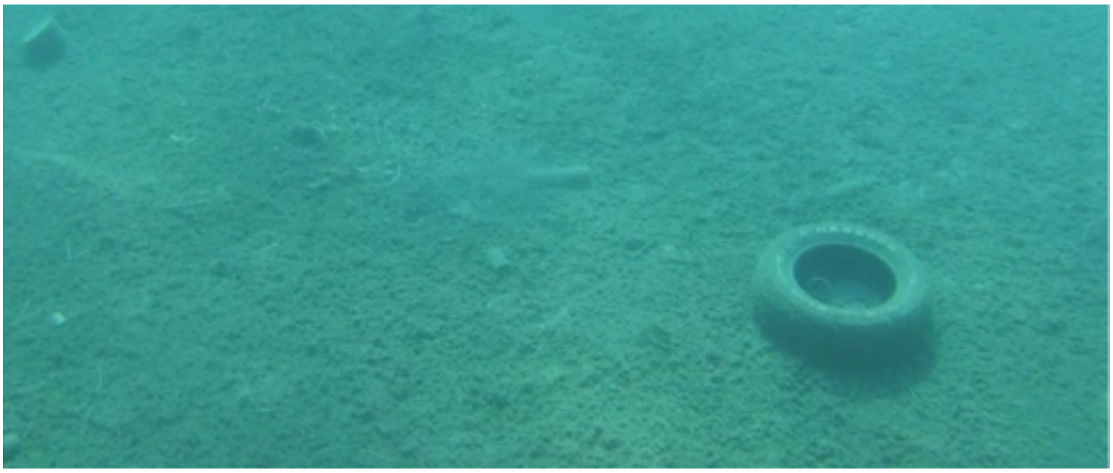

Figure 171 – ("Algae" Fig 1) The area dominated by algae has anoxic sediments as a result of eutrophication. This habitat exhibits very little abundance and diversity. In addition, the invasive species *Caulerpa racemosa* is able to grow in these sediments and is abundant here, restricting the growth of native seagrasses.

Figure 172 – ("Sediment" Fig 1) The shallow area is full of fine sediment which gets suspended during rough weather. This prevents the growth of seagrass and limits the productivity of the bay. UVC, BRUV and fisheries independent netting (Chapter 5) studies showed very little abundance and diversity of species over sand or sediment habitats.

Management Initiative 2 = *Road surfacing and revegetation at Vroulia.*

Supply Chain Risk: The road/path to Vroulia is currently unsurfaced. The path runs from near Platis Gialos on the north coast up and over the island and winds down into Vroulia bay in the north west (Figure 4).

During the winter Lipsi receives heavy rainfall. During this period the heavy rains carve gulley's into the road; and stones and sediment are washed down the path and into the bay (Figure 5). The process of sediment washing off the land and into the bay is known as run-off. Once the the sediment enters the water it loses energy and is deposited close to shore.

Over time this process leads to the accumulation of fine sediments in the bay. This suffocates the *Posidonia oceanica* by blocking the light needed for photosynthesis. This results in seagrass habitat loss, reducing the area covered and the bays contribution to fisheries productivity (Figure 6).

Figure 173 - The road/path to Vroulia is unsurfaced. During the heavy winter rains, both sediment and stones are washed down the path. The water cuts grooves into the surface, restricting vehicle access and flushing further sediment into the bay.

Figure 174 - Photos of Vroulia Bay highlighting the path of the road, and the route taken by eroded sediments into the bay.

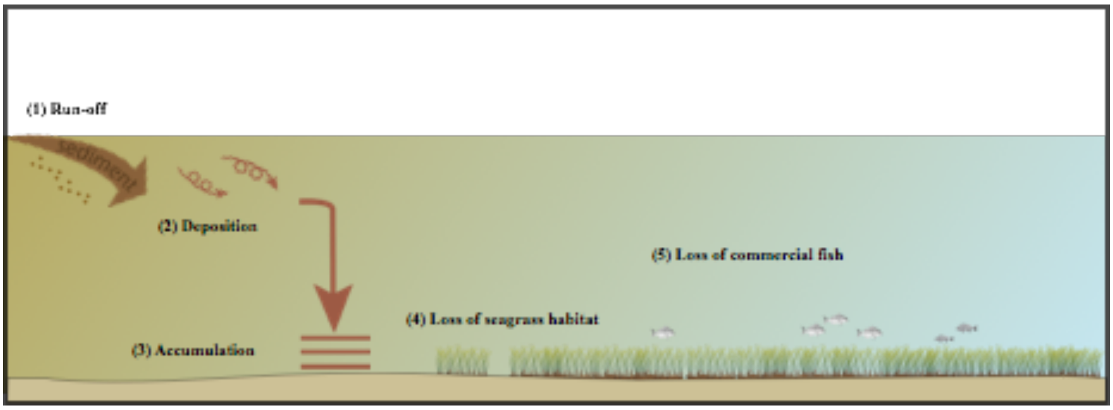

Figure 175 –The process of (1) Run-off of sediments from the land leads to (2) deposition of sediment in the bay. Over time this (3) accumulates, suffocating the seagrass leading to (4) seagrass habitat loss and (5) associated assemblage loss.

Management Opportunity: Surfacing of the road/path with an appropriate drainage system would do much to reduce the volume of sediment entering the bay. Elsewhere on the island, this has proved very effective for example at Kimissi where the road has been surfaced and water drained appropriately (Figure 7)

Figure 176- The surfacing of roads elsewhere on the island, such as Kimissi, combined with appropriate drainage has done much to reduce the volume of sediments being washed into the bay.

In addition, the re-vegetation of the coastline proximal to the bay would do much to reduce the sedimentation of the bay. This would in turn result in improved water clarity and would halt the process of seagrass loss (Figure 6).

Figure 177 - Native shrubs could be planted around the coast to bind the sediment and reduce run off. This would reduce the amount of sediment entering the bay.

Management Initiative 3 = *Mooring Buoy provision at Katsadia / Papadria.*

Supply Chain Risk:

At present *Posidonia oceanica* meadows are being lost around the coast of Lipsi due to anchor damage from recreational boat users. Direct damage to the rhizome mat and canopy can occur from dragging the anchor through a seagrass meadow, or when a force is exerted on the vessel during inclement weather (Unsworth et al., 2017). In addition, scarring can occur around the meadows creating a bare patch or 'halo' effect where the seagrass canopy is eroded by by the movement of the chain (Figure 7).

Figure 178 - Anchor scarring damages seagrass meadows. Such action can result in "halos" around the anchor point [inset – google earth image] reducing seagrass habitat cover.

Over the summer months a popular bar and restaurant on Lipsi attracts numerous vessels into the adjacent bays. Visiting boat users will anchor in the bay and then board the boats 'tender' (a small, usually inflatable vessel) to reach the beach, bar and restaurant. The number of vessels entering the bay can be enormous, for example 43 yachts were recorded on one day in July 2014 (21-07-2014). Such high volumes of recreational boat traffic anchoring in the bay (and other associated activities) is known to have a high impact on the environment (Telesca et al, 2015). To address this issue management effort aimed at reducing this impact should be encouraged.

Figure 179 – Papadria, and the adjacent Katsadia, experience extensive boat traffic (and associated anchoring) over the summer tourist season.

Management Opportunity:

The use of seagrass friendly moorings is a solution to managing the high traffic volumes experienced along Lipsi's southern coastline during the summer months. Conventional yacht anchors will cause damage due to the movement and weight of the chain and anchor (Figure 8). However, a number of 'seagrass-friendly' mooring systems are currently available and have been used with success in other parts of the Mediterranean (Demers et al, 2013).

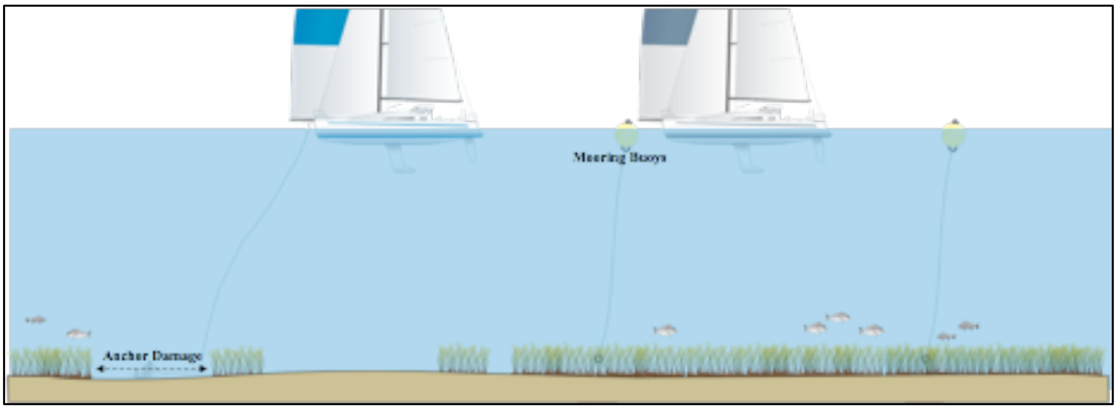

Figure 180 - The provision of public mooring buoys over sensitive marine habitats would provide an alternative to anchoring. This would encourage boat users to utilise the existing anchor points rather than use their own.

The use of such mooring systems in conjunction with some considered marine spatial planning should allow for the safe entry and exit of tourist vessels from the affected bays. To reduce costs, mooring systems need only be placed over seagrass and not over sandy-bottom or rocky-algal habitats which are less productive, and more resilient to anchoring activities.

Figure 181 – The provision of buoys (★) over sensitive marine habitats (e.g. seagrass meadows) for recreational boat users would encoruage users not to anchor in the seagrass. Considered marine spatial planning (-->) would ensure that boats could access and leave the bay safely.

Management Initiative 4 = *Finfish or Lobster hatchery*

A fish hatchery is a *"place for artificial breeding, hatching and rearing through the early life stages of animals, finfish and shellfish in particular"* (Crespi and Coche, 2008). Hatcheries commonly produce larval and juvenile fish, shellfish and crustaceans to support the aquaculture industry. Once juveniles are ready, they proceed along the supply chain to aquaculture farms, it is here they will reach marketable size. There has been much interest over the last two decades in re-stocking overfished stocks by releasing juveniles with the success or otherwise of the process being unique to the species and the place (Munro and Bell, 1997). Decisions to use stock enhancement should be based on thorough pilot studies, including analyses of the range of projected economic and social benefits.

In the USA, there is culturing of finfish larvae for stock enhancement of natural populations (Lee and Ostrowiski, 2001), and in the United Kingdom where a National Lobster Hatchery works on enhancing stocks of lobsters (*Homarus gammarus*) in the coastal waters of Cornwall and the Isles of Scilly. The United States Fish and Wildlife Service (USFWS) have established a National Fish Hatchery System to support the conservation of native species.

Fish stocking is the practice of raising fish in a hatchery and releasing them into the ocean to supplement existing populations, or to create a population where non-exists. There is much need for such practice around the coastal waters of Lipsi. However, there are numerous species-specific difficulties in instigating this in practice. One example, the dusky grouper (*Epinephelus marginatus*) is a serranida species with great ecological importance, social importance (Figure 10), and good perspectives for rearing (Kerber et al, 2012).

Figure 182 - A Dusky Grouper (*Epinephelus marginatus*) in the Crete Aquarium, and on a Greek stamp [inset]. (Photo credit: CretAquarium)

As a result of the substantial decline in total catches in many fishing areas, *E. marginatus* was placed on the IUCN Red List and classified as an endangered species in 1996. In addition, since 1995, the dusky grouper was added to the endangered Teleost List in Annex 3 to the Berne Convention (1996), under which management measures must be planned and aquaculture maintaining, and breeding techniques developed, in order to increase and repopulate endangered stocks (Kerber et al, 2012). An urgent need since recent re-evaluation of its population shows that the wild population is still decreasing (Cornish and Harmelin-Vivien, 2011). Currently, one of the major obstacles to propagating is the difficulty of rearing the early larvae (Kerber et al, 2012).

Another potential hatchery could be the European spiny lobster, *Palinurus elephas* (Figure 12). This species has a high ecological, conservation and socio-economic importance, with price on the EU market fetching between €40–120 per kg (Groeneveld et al, 2013). Currently, the culture technology is being piloted by RAS Aquaculture Research Ltd (RASAR); During 2013 RASAR advanced the culture techniques and understanding of this species further than any other research group in Europe and having just completed construction of a new purpose-built laboratory in 2014 it can be expected that RASAR will be in a position to advise on hatchery development in the near future (oceanologyinternational.com).

Figure 183 - A European spiny lobster, *Palinurus elephas* caught in a Trammel net. The lobster was caught in Coralline alga habitat off Lipsi's west coast.

The repercussions of poorly regulated and mismanaged aquaculture are clearly visible in Moschato and with more commonly reared species such as the Sharpsnout sea bream, *Diplodus puntazzo,* there is already documented in Greece the risks of bacterial pathogens; that can affect a broad range of aquaculture fish species (Katharios et al, 2015). However, due to the current poor state of this bay and the need to rehabilitate the ecosystem, the proximity of the bay to both *Posidonia oceanica* meadows and *Coralline alga* habitat, and the isolation of the facilities from tourism would make these bays the ideal candidates for a fish hatchery developed for fish stocking purposes. In fact, a 'Lipsi Lobster Hatchery' could actively promote 'Green Tourism; in a similar manner to the National Lobster Hatchery in the UK (http://www.nationallobsterhatchery.co.uk).

Figure 184 - The bay of Moschato (yellow) would be the preferred location for a Dusky Grouper farm. The building and bay of Vroulia (green) would be the preferred location for a lobster hatchery.

Management Initiative 5 = *Marine Special Area of Conservation*

Ensuring the perpetuity of the broad assemblage of species characteristic of the Aegean Sea will require immediate and coordinated action at large spatial scales. The sustainability of the Lipsi fishery supply chain largely depends upon decisions that affect the marine environment at the regional level, rather than at the local.

Lipsi currently falls under site code GR4210010 as a Natura 2000 site. The Natura 2000 network is a network of nature protection areas in the territory of the European Union. The site was first proposed as a Site of Community Importance (SCI) in August 1998. In September 2006 it was confirmed as an SCI. Later, in March 2011, the site was designated as a Special Area of Conservation (SAC) under the EU Habitats Directive.

At present, the site includes 12,407ha of terrestrial ecosystems but 0ha of marine ecosystems. At present site GR4210010 is composed by the inhabited islands Arki, Lipsi and Agathonisi, the small islets around them as well as the isolated islets lying eastwards of the main islands of Leros and Kalymnos. These are: Kalapodi (2 islets), Tripiti (2 islets), Pharmakonisi, Kalolimnos, Pitta, Prassonisi and Imia (2 islets). The whole complex belongs to the Dodecanese and is situated at its northern part.

The suggestion presented here is to extend the current SAC territory to include the marine ecosystem. Especially since the European Commission has acknowledged that the creation of a network of marine areas is a priority, that Europe's seas are under pressure, and that Marine protected areas (MPAs) can act as a key conservation measure to safeguard marine ecosystems and biodiversity as well as the services these ecosystems provide (EEA Report No3/2015).

It is suggested that industrial fishing be prohibited from these waters which would immediately reduce fishing pressure, it may also serve to protect Gilthead sea bream *(Sparus aurata)* spawning grounds; the fish are reported to spawn in the waters between Kalymnos and Turkey around May, and currently suffer from exploitation during this period (Fisherman 22-06-2014).

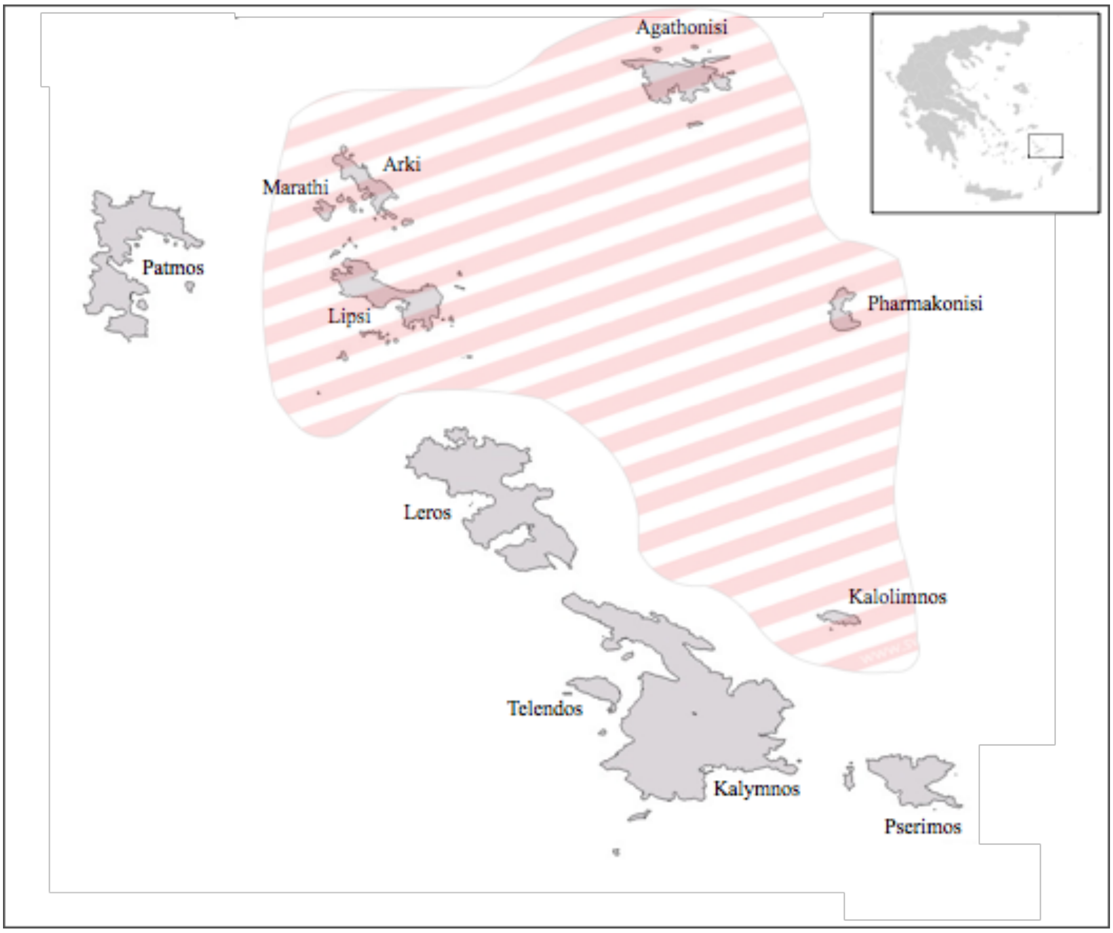

Figure 185 - The Natura 2000 site (GR4210010) with proposed expansion into the marine environment (red stripes).

Whilst the sustainability of the Lipsi fishery requires change in fishing practice and legislation at the regional level, at the local level much can still be done to ensure sustainability of the small-scale capture fishery supply chain. The head of the Lipsi Fisherman's Association advocates for the establishment of a Marine Protected Area (MPA) near Lipsi in conjunction with a closed fishing season or temporary suspension of fishing activity (Pers. Comm.).

The island group of Makronissi in combination with the waters up to the island of Fragos are suggested here as a potential site for this Marine Reserve. On the basis of a suggested 14km perimeter delineating the MPA around the islands of Makronissi and Fragos an expected area of around 1200ha/12km^2 (inclusive of islands) could be fully or partially protected from extractive fishing activity (Figure 15).

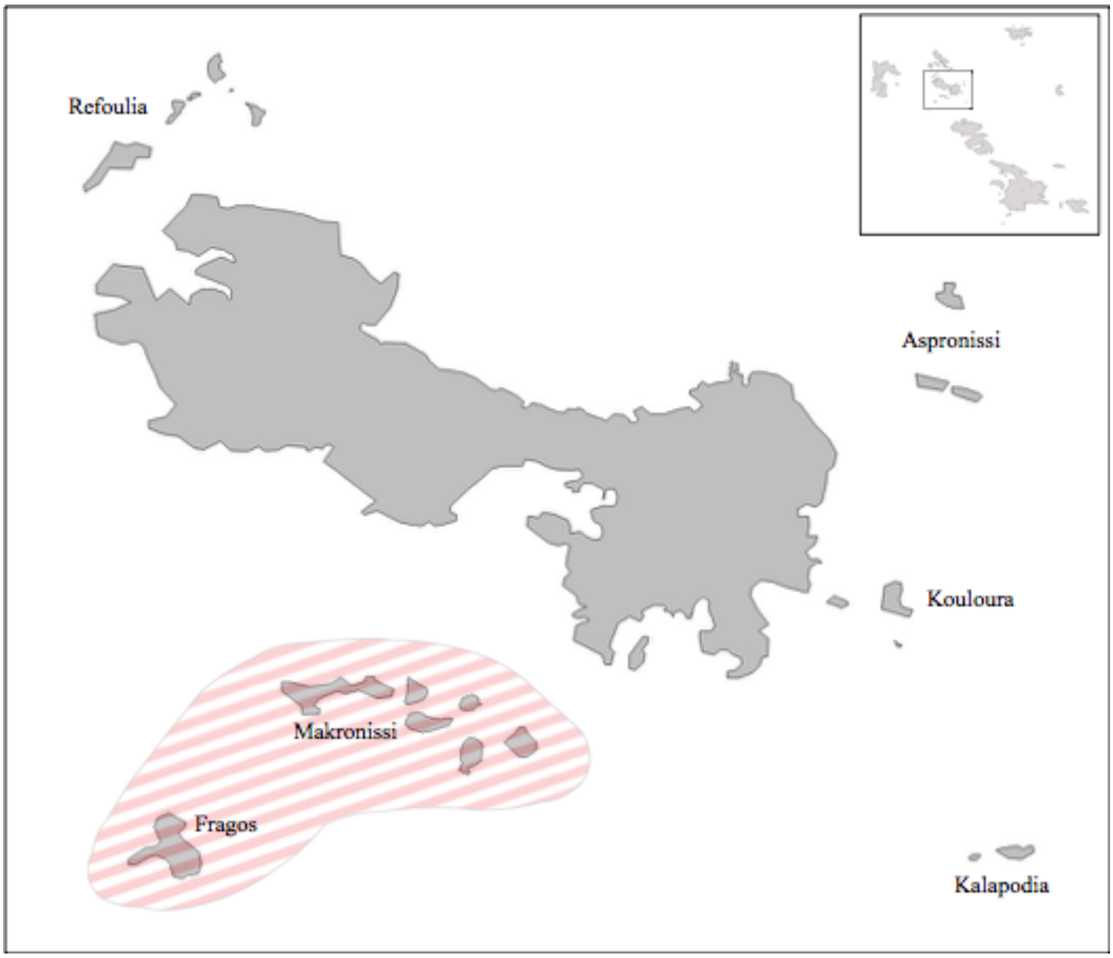

Figure 186 - The proposed Marine Protected Area (Makronissi and Fragos)

There is a growing interest in the development of MPAs globally due to their success in aiding stock recovery and protecting essential fish habitats (Lotze et al, 2006). There are several different levels of MPA protection from highly protected where all fishing activities are displaced (Westcott, 2006) to multiple use MPAs (Agardy, 1993). Matching marine reserve design to reserve objectives (Halpern and Warner, 2003) is crucial due to the considerable impact it can have on livelihoods, for this reason their value as a means of stock protection and recovery have to be clearly and convincingly shown (Silvert and Moustakas, 2011). In the short term, the management regime of the proposed MPA could be economically disadvantageous to some fishers, with the size and age of reserves (Claudet et al, 2008) known to significantly effect their positive refuge effects. That said, the reserves can also be economically advantageous to recreational sectors (Rees et al, 2010), with eco-tourism activities (see 9.4) often founded following the establishment of an MPA (Merino et al, 2008). Two similar reserves have already been founded in the Western Mediterranean.

The proposed reserve would be roughly double the size of the Scandola Nature Reserve located on the west coast of the French island of Corsica. Founded in 1975 at a site recognized as World Heritage by UNESCO, the Marine Reserve of Scandola (590 ha) is one of the oldest Mediterranean MPAs and benefits from well-enforced protection measures (Gabrié et al., 2012). It includes a no-take area or integral reserve (IR: 72 ha), where most human activities (including fishing, diving, and boat anchoring) are prohibited, and partially protected areas or buffer zones (BZ: 518 ha), where professional fishing activities only are allowed under certain conditions (i.e. using small boats with low-powered engines and traditional fishing methods). In unprotected zones (UP) outside the MPA, all types of professional and recreational fishing are allowed, including spearfishing (Harmelin-Vivien et al, 2015). The number of large fishes (matured adults) is much higher within the reserve and is characterized by both more, and larger fishes, a greater variety of species and the conspicuous presence of charismatic species e.g. *Dicentrarchus labrax, Sparus aurata, Epinephelus marginatus, Sciaena umbra.* (Francour, 1994; Harmelin-Vivien, 2015).

Another, similar example is the Medes Islands Marine Reserve which have been a protected area since 1983 off the coast of L'Estartit, in Catalonia, Spain (Figure 16). The MPA is part of an archipelago composed of seven islands and islets comprising a total area of 511ha (Martín et all, 2012). It includes a no-take area or integral reserve (IR: 23ha) with the remaining a partially protected buffer zone (BZ: 488ha). Outside of the reserve all types of professional and recreational fishing are allowed, including spearfishing (Martín et al, 2012). This reserve again shows the benefit of protection and in addition have fostered a booming tourist trade as a major SCUBA diving destination, with 55,657 dives registered in the MPA in 2012 (Rodrigues et al, 2015). With the tax revenue obtained from scuba diving and snorkelling activity representing approximately 50% of the total budget of the management of the MPA in 2009 (Quintana and Hereu, 2012 in Rodrigues et al, 2012).

The creation of a fully protected, or partially protected, Makronissi Marine Reserve could have numerous direct benefits including spill-over effects to the fishery (Vandeperre et al, 2011; Martín et al, 2012), direct income from increased tourism (Merino et al, 2009; Sala et al, 2013; Rodrigues et al, 2015) and indirect benefits pertaining to a raised international profile.

Figure 187 – (A) The islets of Makronissi and Fragos, as viewed from Kimissi tis Theotokos. (B) The Medes Islets seen from the Montgrí Massif. The Makronissi and Fragos islands could foster a similar productivity to the reserves of the Western Mediterranean.

10.4.2 Demand-Side Initiatives

Management Initiative 6 = *Transition towards an Eco-tourism model*

According to The International Ecotourism Society (2015), Ecotourism is now defined as *"responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education".* Ecotourism is about uniting conservation, communities, and sustainable travel. Key to eco-tourism are conservation initiatives, that offer market-linked long-term solutions that offer economic incentives for conserving and enhancing both social and and ecological diversity (TIES, 2015).

Since the early 1900s biologists have been collecting data on the islands and islets of the northern Dodecanese (Panitsa and Tzanoudakis, 2001 and references therein) with exceptional biodiversity being recorded across the region (Panitsa et al, 2010). Botanists have recorded a number of endemic species such as *Allium dodecanesii* alongside studies on reptile fauna (Foufopoulos, 1997) and avifauna (Panitsa and Tzanoudakis, 2001) and the data presented in this thesis suggests that there is a wealth of marine life present in Lipsi's coastal waters.

In the Northern Dodecanese a wildlife refuge has been established comprising fourteen islets in the Arki area. There have also been plans to extend it to create a maritime park called "Northern Dodecanese Islands and Islets National Park" in the archipelago of Lipsi, Arki and Agathonisi" with a total of 52 islands and islets but as yet this has yet to come to fruition (Broggi, 2008). Contuining to pursue the development of such a 'national marine park' could serve to not only direct the tourism 'philosophy' in the area towards a more ecologically minded development practice but could also serve as a platform from which to establish a Marine Protected Area (as discussed in Management Initiative 5).

Panitsa and Tzanoudakis (2001) have previously suggested that Eco-tourism is the most appropriate model for sustainable development in the area. The pursuit of sustainable development models linked to snorkeling of SCUBA operations could provide alternative livelihoods on the island like such operations have elsewhere.

Management Initiative 7 = *Education and Ocean Literacy*

A major issue relating to the sustainability of the supply chain is the attention given to seagrass ecosystems and the lack of attention in popular media. Seagrass ecosystems receive the least attention in the media (1.3% of the media reports) with considerably more attention on being given to mangroves (20%), and a dominant focus on coral reefs, which are the subject of three in every four media reports on coastal ecosystems (72.5%) (Duarte et al., 2008).

More effective communication of the scientific knowledge about Lipsi's *Posidonia oceanica* habitat is required. Seagrass meadows might well be uncharismatic, but they are ecologically important coastal habitats.

Effective use of formal educational channels (e.g., school curricula, media) and informal (e.g., web) education avenues are an important step in this regard. Formal educational resources are available such as the Frontiers for Young Minds seagrass paper *'Secret Gardens Under the Sea: What are Seagrass Meadows and Why are They Important?'* (Cullen-Unsworth et al, 2018) can provide accessible science to school children. The International NGO Project Seagrass provides a suite of resources through their Seagrass Education and Awareness Programme (http://www.projectseagrass.org/education) and a smartphone application to encourage participation in outdoor learning and interational Citizen Science activities (https://seagrassspotter.org).

Figure 188 – Seagrass Spotter is a global smartphone app designed to encourage Citizen Science.

An effective partnership between scientists and local media communicators are likely essential to raise the local awareness of issues, concerns, and solutions within Lipsi's coastal ecosystems. Only through increased public understanding of the ecological issues present in place will change be able to come (Duarte et al., 2008). Ultimately, it is up to the local community to inform visitors of their importance and to motivate effective Sustainable Supply Chain Management of these ecologically important coastal ecosystems.

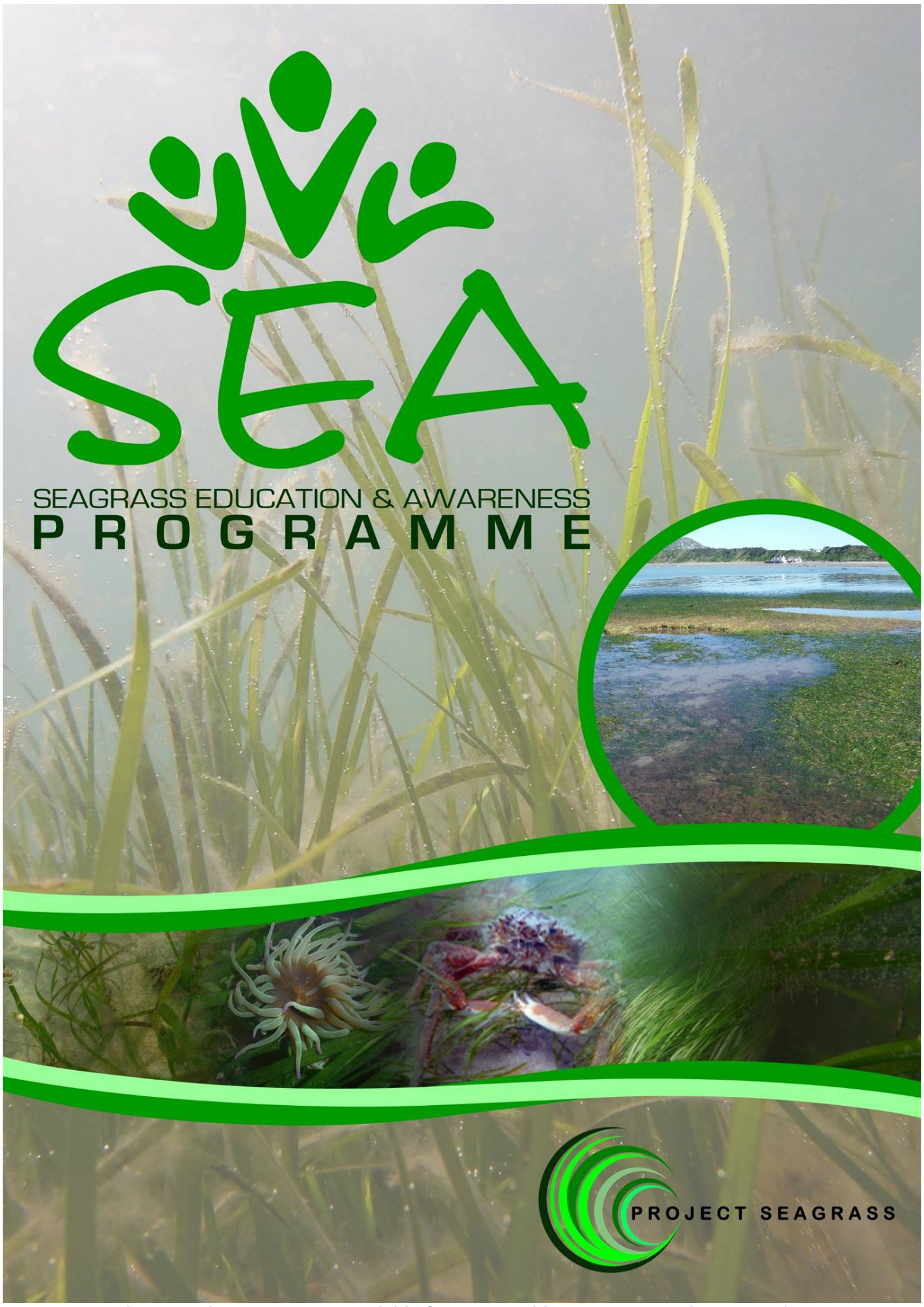

Figure 189 - Educational resources are available from reputable environmental NGOs such as Project Seagrass (ProjectSeagrass.org)

Management Initiative 8 – *Seafood Marketing of more sustainable fish*

For some, a visit to a new place offers the opportunity to engage in a culture and lifestyle that is dissimilar to one's place of origin. Often this will involve the consumption of traditional foods which are an expression of the culture, history and lifestyle of the place in question (Trichopoulou et al., 2007). Despite the fact that we are now living in a world of globalized supply chains, different dietary patterns between places do still exist (see Slimani et al., 2002) and thus travel for food has become a research focus in tourism and hospitality (Hall and Gössling, 2016).

One element of this is that many traditional foods and consumption patterns are understood to have health properties (which have, by default, been tested over time) and much has been made of the 'traditional Mediterranean diet' on the basis of both observational studies (Willet et al., 2006) and via randomized trials (Estruch et al., 2006). For example, it has been shown that the beneficial effects of the traditional Mediterranean diet are attributable to the dietary pattern as a whole rather than to single components or single nutrients. It may be that the biological interactions between different components of the Mediterranean diet are responsible for the apparent beneficial health effects (Trichopoulou et al., 2003), but the beneficial effects can also be attributed to traditional foods that incorporate the knowledge and wisdom of past generations (Traditional and Local Knowledge) who, living under difficult conditions have learnt how to optimize use of locally available ingredients in order to produce palatable foods and recipes with potential to improve human health (Trichopoulou et al., 2000).

But, 'traditional foods' are now also changing, local seafood supply is not a static concept, with climatic change causing the migration of fishes either to higher latitudes or deeper depths (Norse et al., 2012). This is particularly true in the south-east Mediterranean, where, after the opening of the Suez Canal in 1869, there has been an influx of Red Sea and Indo-Pacific organisms into the Meditteranean Sea. This phenomenon is known as the 'Lessepsian Migration' (Por, 1978). According to Zeneteos et al. (2008) at least 903 species have been introduced into the regional seas, with new species introductions calculated to be in the order of 1 species every 10 days (Zenetos, 2010).

One such species (that is now dominating the Lipsi SSCF catch; 30.5% of annual abundance, 71.9% of catches – see Chapter 7) is the Dusky spinefoot (*Siganus luridus*), which was first discovered in Israeli waters in 1955, arriving in Greece a few years later and which therefore plays no part in the 'traditional Mediterranean diet'. The species is replacing native herbivores and drastically changed the dynamics of energy flow through the food web (Galil 2007). However, such is the volume of individuals now present in Greek waters, that it has become a species of commercial importance in the eastern and central south Mediterranean Sea (Zenetos, 2010).

The globalistaion of supply chains has meant that the historically large differences between Mediterranean and northern European populations' food consumption patterns appear to be diminishing (Trichopoulou et al., 2007); particularly as contemporary patterns reveal Mediterranean populations straying from their traditional dietary choices (Karamanos et al., 2002) and where, for example, Northern European populations are now increasing their consumption of fruits and vegetables (Trichopoulou et al., 2007). The current public interest in nutrition and healthy eating has contributed to an increased demand for 'traditional' foods with many supply chains responding to such consumer demand side pressures. (Allende et al., 2006). If research could be done into, for example, the 'health benefits' of rabbitfish (*Siganus luridus* and *Siganus* rivulatus) consumption then perhaps there is scope for marketing these Lipsi SSCF abundant species internationally?

Place-based solutions for creating supply chain demand locally, could be the continued harvesting of these species by the fishing fleet, but supplemented by a deliberate marketing campaign to encourage tourist consumption. One way this could be done is to encourage spearfishers to target the species, creating an effective social medium for raising the profile of the species and shifting supply chain away from species that are currently overfished.

Spearfishing, in particular, is an area to target because of their tendency to traditionally target high value species (e.g. Grouper) but also because of the absence of undesired bycatch from this fishing technique. In the USA, recent targeting of Lionfish by divers has resulted in over 1400 lionfish being collected in one day during a derby-style event (Morris and Whitefield, 2009) and so perhaps some of the similar social-economic strategies that have been successful in the USA could be applied to the Mediterranean. Indeed, it may provide the opportunity to develop both a market, and culture for targeted extraction of species through such events; something that may well prove useful ahead of the predicted invasion of Lionfish over the comings decades (Kletou et al., 2016).

It is argued that fundamental economic considerations are ultimately the determinants of supply chain parameters, determining shape, size and the nature of exchange (Casson, 2013). However, other drivers are also known to shape the size and nature of exchange, from regulatory frameworks, to sustainability agendas (Pagell and Wu, 2009), to political motivations (Gereffi, 2014) and individual organizations' strategic choices (Ketchen and Giunipero, 2004). In encouraging the Lipsi Small-Scale Capture Fishery (SSCF) towards sustainability, Sustainable Supply Chain Management (SSCM) measures that provide the necessary conceptual frameworks for discussion between multiple stakeholders must be championed, such as the 'Habitat to Consumer' conceptual framework presented in this thesis.

Global sourcing strategies have already changed the configuration of supply networks significantly (Jia et al., 2014), and it is now up to organisations to pro-actively re-design their socio-economic networks to pursue a marketing strategy that better matches their available product supply (MacCarthy, 2016). The Lipsi Small-Scale Fishery can't change, evolve or improve its species, (biological evolution takes time!) but it, and the Municipality can be part of a wider strategy that encourages the Sustainable Supply Chain Management of local seafood stocks, and the targeted consumption of certain local species (e.g. *Siganus luridus*) over other less sustainable options, and markets them accordingly. Thus, a range of economic, technological, environmental and strategic factors can potentially influence who participates in supply chains, where value adding activities occur, how they are coordinated and managed, and how they develop and grow (MacCarthy, 2016).

The marketing of an invasive species for human conception is not a strategy without precedent. Venomous Indo-Pacific lionfish (*Pterois miles* and *Pterois volitans*) are now established in the southeast USA and parts of the Caribbean (Morris and Whitfield, 2009) (they were first noted in the 1980s along south Florida and *Pterois miles* was this summer recorded for the first time in the Mediterranean too, Kletou et al., 2016). These invasive species pose a serious threat to fish communities of these regions and thus the consumption of this species has been encouraged as medium for creating consumer driven supply chain demand and novel seafood supply chains. The creation of a wide-scale rabbitfish marketing strategy is problematic, given the broad, international distribution and high densities (Poloniato et al., 2010). However, control strategies for smaller populations, such as around Lipsi and the northern Dodecanese where rabbitfish are found in shallow and near-shore waters (see Chapter 6) are likely more practicable.

The human consumption of rabbitfish (Siganidae) is a plausible option for creating supply chain demand, since rabbitfish meat is both mild and firm, and therefore possess the necessary qualities for edible and palatable fish. Indeed, the family is an established food fish in the Indo-Pacific region (Pers. Obvs) and therefore with careful marketing there is no reason why supply chain demand could not be transferred to the Mediterranean. A similar 'ugly' and venomous seafood species is the scorpionfish (Scorpaenidae) are considered a delicacy in French cuisine (i.e. rascasse and bouillabaisse). On Lipsi this family is already a popular fish for residents and therefore there is the basis from which to raise the profile of non 'silvery' fish and develop markets (both locally, regionally and with tourists) that could create a demand for Rabbitfish and provide additional incentives for harvesting.

10.5 Multi-stakeholder solutions

Better management of the fishing industry can undoubtedly have major, positive social, economic and ecological benefits. For example, Costello et al. (2016) suggest that improved fisheries management would not only assist the recovery of more than 90% of currently depleted fish stocks, but also significantly boost profits generated from harvesting those stocks. Previously, Árnason et al. (2009) estimated that there was $50 billion (USD) of economic benefits "the sunken billions" lost annually because of poor fishing practices (that damage coastal habitats) and sustained overfishing (running stocks to ecological collapse).

It is recognised that to secure sustainable small-scale fisheries will require input from states, civil society, fishing communities and the organisations and business, and that responsible fisheries management, human rights and sustainable development go hand-in-hand.

For this reason, when planning and implementing Sustainable Supply Chain Management (SSCM) initiatives stakeholders need to take an inter-sectoral approach, ensuring that the department responsible for fisheries coordinates with that responsible for the environment, for decent and fair working conditions, or for the more basic needs such as health, housing and social development. For effective SSCM a 'holistic approach to governance must be undertaken that seeks to integrate the Ecological, Social and the Economic, but whilst adhering to governance by Ecologically dominant principles. Stakeholders could also benefit by collaborating across spatial scales, from the local to the regional, and the national to the international.

In order to use this 'Habitat to Consumer' framework as a platform from which to achieve more sustainable fisheries management on Lipsi, it is suggested that the conceptual framework presented could be used as a common platform for discussion. The conceptual framework could also act as a medium through which the community could be involved in discussing the management challenges facing the fishery as an extractive industry, and how those seafood resources present in the

Lipsi seascape, might be managed in a more sustainable way.

Sustainable Supply Chain Management has the capacity to engender equitable participation of fishers (especially women) by promoting co-management, but the activities to prevent illegal fishing and promote conservation will also likely be place-specific, and thus be designed to fit the community they are operating in.

The Lipsi community needs secure access to both the land, and to the waters where they fish, with an explicit recognition that small-scale fishery supply chain depends on those marine ecosystems (habitats and assemblages) that link the communities' life on land to the marine environment'. When planning coastal development, it is therefore both the local community, and elected government's responsibility to ensure that both the land and the marine ecosystems remain healthy and able to sustain these livelihood's.

Finally, when making plans that involve fisher communities, it is important that activities all along the value chain are considered. This includes, but are not limited to mending nets, preparing bait, harvesting different marine resources, as well as those activities that add value, such as cleaning, smoking, packing, and marketing fish, or are of broader community benefit sharing such as local tourism and conservation. Ideally, governments need to provide infrastructure, co-ordinate capacity building programs and provide the necessary resources for the development of low-cost information and communication technologies.

Innovative technologies such as these could enable small-scale fishes to capture and share their data, access information about markets and trade, control the value chain more effectively. This would also help promote traceability (see FollowFish.de). Such actions can help shift power relations in the marketplace towards the small-scale fishers, promoting equality and strengthening accountability to the local community.

Fundamentally, it is important to recognise that different stakeholders in Lipsi, have different objectives for the local marine ecosystem, all of which cannot be met. Creating a platform for discussion based around the SSCF conceptual framework is just the start for articulating the need to transition towards extractive sustainability and sustainable place creation.

On an individual stakeholder level, creating an alternative to the "winner takes all" mentality (the mind-set which game theorists call a "zero-sum" game and in which individual stakeholders are resigned to a win-lose outcome) will require a concerted effort from multiple stakeholders to achieve. However, like Elliot Norse (2010) said; *"In this time of profound change… plus-sum games with win-win outcomes are not only essential, they are possible"*

Therefore, rather than being the 'intransigent victims of change' all stakeholders must find ways to deal with the changes they are experiencing. This thesis has shown that the Lipsi fishery is currently in a degraded position, which must compel stakeholders with different objectives to work together to protect, recover and maintain the SSCF seafood supply chain. If it doesn't, then this is more a problem of identity and culture… What does the existence of the SSCF mean to the community, and to Greece?

"The obscure we see eventually. The completely obvious, it seems, takes longer,"

Edward R. Murrow, American journalist, 1908–1965

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APPENDIX

APPENDIX

I. Research Agreement Form:

Objectives of the research

The overall aim of this research is to conduct a socio-ecological study to assess the fish stocks and eating habits of the population of Lipsi. This is to ensure food security, which can be defined as "the ability of the world to provide healthy and environmentally sustainable diets for all its peoples". By conducting both ecological studies and collecting fisheries landing data we can obtain important information on local fish stocks. Using this information, we can promote sustainable resource exploitation that enhances the productive capacity of the fishery and ecological system.

Στόχοι της έρευνας

Με αυτήν την έρευνα, στόχος μας είναι να διεξάγουμε μία κοινωνικο-οικολογική μελέτη για την εκτίμηση των αλιευτικών αποθεμάτων και τις διατροφικές συνήθειες του πληθυσμού των Λειψών. Αυτό γίνεται για να εξασφαλιστεί η ασφάλεια των τροφίμων, η οποία μπορεί να οριστεί ως «η ικανότητα του κόσμου να εξασφαλίσει μία υγιή και περιβαλλοντικά βιώσιμη διατροφή για όλους τους λαούς της». Με τη διεξαγωγή των οικολογικών μελετών και της συλλογής αλιευτικών δεδομένων μπορούμε να λάβουμε σημαντικές πληροφορίες σχετικά με τα τοπικά ιχθυαποθέματα. Χρησιμοποιώντας αυτές τις πληροφορίες μπορούμε να προωθήσουμε τη βιώσιμη εκμετάλλευση των πόρων, η οποία ενισχύει την παραγωγική ικανότητα των αλιευμάτων και τα οικολογικά συστήματα της περιοχής.

Do you agree to participate in this study?

Έχετε συμφωνούν να συμμετάσχουν σε αυτή τη μελέτη;

Name / Όνομα: ___________________________ Date / Ημερομηνία: ___________

You may withdraw from the study at any time and for any reason. Your data will be treated with full confidentiality, and will not be identifiable as yours in any published findings.

Μπορείτε να αποχωρήσετε από τη μελέτη οποιαδήποτε στιγμή και για οποιονδήποτε λόγο. Τα δεδομένα σας θα πρέπει να αντιμετωπίζονται με πλήρη εχεμύθεια και δεν θα είναι αναγνωρίσιμα τα δικά σας κατά τη δημοσίευση των ευρημάτων.

II. Fishery Landings Data Form

Species:	Size (cm)						

III. Reported Fishery Data Form – Part I

Form Number: (Arithmos phormas):		**Name of captain:** (Onoma kapetaniou):	
Date: (Imerominia):		**Boat Name:** (Onoma skaphus):	
Time returned from collecting nets: (Ora epistrofis apo to mazema tou dixti):		**Boat Number:** (Arithmos skaphus):	
Recorded by: (Simplirothike apo):		**Fishing Location:** (Alievtiki periochi):	See Map

When did you leave to set your nets? Ti ora piges na rixis ta dichtia?	
How long did it take to get to your destination? Pósi óra ekanes na ftasis ston proorismo sas?	
How long was your gear in the water? Posi ora ítan ta ankistria sti thálassa?	
How long did it take to put your gear in the water? Posi ora sou pire na rixis ta dichtia?	
How long did it take to take your gear out of the water? Posi ora sou pire na sikosis ta dikhtia?	

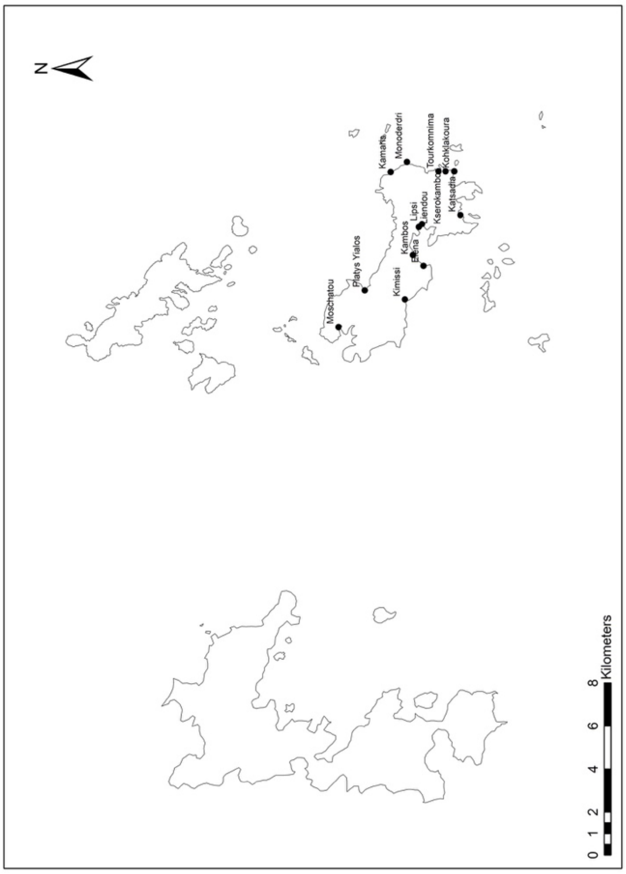
Substrate:	**Rock**	**Seagrass**	**Sand**	**Corraligene**
(Tick)	*(Vrachia)*	*(Posidonia)*	*(Ammos)*	(Tragana)

Nets (Dikhti) (number) (arithmos) **Gill / Trammel?** (Apladia / Manomena)		**Long line** (Paragadi) (number) (arithmos)		**Traps** (Kirtos) (number) (arithmos)	
Depth Range: (Vathos (euros)			**To:** (ews)		

Length of net / long line / trap size: (Mikos: dikhtiu / paragadiu / Megethos kirtu)	
Width of net / no of hooks / trap diameter: (Platos dikhtiu / Arithmos ankistrion / Diametros kirtu)	
Mesh size / size of hooks: (Megethos matiu)/(Megethos ankistrion)	
Bait used: (doloma):	

III. Reported Fishery Data Form – Part II

Sea state: (katastasi thalassas)	Calm	Slight	Moderate	Rough					
Wind Strength: (entasi anemou)	1	2	3	4	5				
Cloud cover: (oktas (kalupsi nefon):	0	1	2	3	4	5	6	7	8



IV Fishers Ecological Knowledge – Part I.

Semi-structured Interview applied in interviews with coastal fishermen in Lipsi, Greece.

This questionnaire was targeted to fishers. All interviews were conducted in private in order to minimize the effects of other fishers' presence on the answers given. The older, most experienced fishers who were retired from fishing activities were visited and interviewed in their households. We obtained written consent from participants before conducting interviews, and fishers were informed on the purpose of the research. Interviews were conducted by Lydia Vavoula.

Έντυπο: Form:	Ημ/νία: Date:	Ώρα: Time:	Σχόλια: Comments:

Age / Ηλικία :

( ) 20-29

( ) 30-39

( ) 40-49

( ) 50-59

( ) 60-69

( ) 70+

Φύλο Sex:

Α M♂

Γ F♀

1. How many years have you been fishing (for income)?

( ) <10 years

( ) (10-19 years)

( ) (20-29 years)

( ) (>30 years)

2. Is fishing your only source of income? ( ) Yes ( ) No

IV Fishers Ecological Knowledge – Part II.

3. How would you describe the current conditions of fish stocks regarding abundance?

a) Over the last 5 years

( ) unaltered ( ) declined ( ) increased

b) Over the last 15 years

( ) unaltered ( ) declined ( ) increased

4. Are there any overexploited fish species in this region? ( ) Yes ( ) No

If Yes, which species? ____

5. Are there any species that you discarded in the past (not good enough to eat or sell) that today are eaten/sold

( ) Yes ( ) No

If Yes, which species? ____

Why is this species now kept?

6. Is there a place in this region that was considered a good fishing site in the past due to the abundance and productivity of fish, but nowadays is considered overexploited? ( ) Yes ( ) No

When did that change?

7. Which area should be protected from fishing (if any)? Why?

8. What (management) measures do you think are important to improve the catch/landings (and therefore income) in this region?

V. Household Survey Form:

<table>
<tr><td>Έντυπο:
Form:</td><td></td><td>Ημ/νία:
Date:</td><td></td><td>Ώρα:
Time:</td><td></td><td>Προσωπικό:
Staff:</td><td></td></tr>
<tr><td>Ηλικία
Age</td><td>20-30</td><td>30-40</td><td>40-50</td><td>50-60</td><td>60-70</td><td colspan="2">70+</td></tr>
<tr><td colspan="3">Φύλο
Sex:</td><td colspan="2">Α
M ♂</td><td colspan="3">Γ
F ♀</td></tr>
<tr><td colspan="3">Εθνικότητα
Nationality:</td><td colspan="5"></td></tr>
<tr><td colspan="3">Πόσο καιρό ζείτε στους Λειψούς;

How long have you lived on Lipsi?</td><td colspan="5"></td></tr>
<tr><td colspan="3">Πόσες μέρες την εβδομάδα τρώτε θαλασσινά;
How many days per week do you eat seafood?</td><td colspan="5">1 | 2 | 3 | 4 | 5 | 6 | 7</td></tr>
<tr><td colspan="3" rowspan="5">Τα 5 καλύτερα ψάρια προς κατανάλωση
Top 5 Fish to Eat:</td><td colspan="5"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="3">Από πού τα προμηθεύεστε;
Where do you buy it?</td><td>Εστιατόριο
Restaurant</td><td>Αγορά
Shop</td><td colspan="3">Ψαράδες
Fishermen</td></tr>
<tr><td colspan="8">Σχόλια:
Comments:</td></tr>
</table>

VI. Visitor Exit Survey:

<table>
<tr><td>Έντυπο:
Form:</td><td></td><td>Ημ/νία:
Date:</td><td></td><td>Ώρα:
Time:</td><td></td><td>Προσωπ
ικό:
Staff:</td><td></td></tr>
<tr><td>Ηλικία
Age</td><td>20-30</td><td>30-40</td><td>40-50</td><td>50-60</td><td>60-70</td><td colspan="2">70+</td></tr>
<tr><td colspan="3">Φύλο
Sex:</td><td colspan="2">Α
M ♂</td><td colspan="3">Γ
F ♀</td></tr>
<tr><td colspan="3">Εθνικότητα
Nationality:</td><td colspan="5"></td></tr>
<tr><td colspan="3">Διάρκεια διαμονής / αριθμός ημερών
Duration of stay / no of days</td><td colspan="5"></td></tr>
<tr><td colspan="3">Πόσες φορές φάγατε θαλασσινά κατά τη διάρκεια της διαμονής σας;
On how many occasions did you eat seafood during your stay?</td><td colspan="5"></td></tr>
<tr><td colspan="3">Τι είδους θαλασσινά φάγατε;
What kinds of seafood did you eat?</td><td colspan="5"></td></tr>
<tr><td colspan="3">Από πού τα προμηθευτήκατε;
Where did you buy it?</td><td>Εστιατόριο
Restaurant</td><td colspan="2">Αγορά
Shop</td><td colspan="2">Ψαράδες
Fishermen</td></tr>
<tr><td colspan="8">Σχόλια:
Comments:</td></tr>
</table>