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# Preparing ocean governance for the challenges of species on the move

New policy approaches are needed to prevent international conflict over geographic shifts in fished species

By Malin L. Pinsky<sup>1\*</sup>, Gabriel Reygondeau<sup>2</sup>, Richard Caddell<sup>3,4</sup>, Juliano Palacios-Abrantes<sup>2</sup>, Jessica Spijkers<sup>5,6</sup>, and William W. L. Cheung<sup>2</sup>

The ocean has provided food to humans for millennia, remains a critical source of nutrition for billions of people today, and has the potential to yield further food, profits, and employment in the future (1). We believe fisheries now face a significant new challenge, however, as climate change drives the ocean to conditions not experienced historically. The rapid, locational shifts in marine animals driven by a warming ocean represent an emerging situation for which local, national, regional, and international fisheries are substantially underprepared. Fish and other animals have already moved at a rate averaging 70 km decade<sup>-1</sup> (2), and these shifts are expected to continue or accelerate (3). We show here that many species will likely shift across national boundaries in the coming decades, creating the potential for conflict over newly shared resources.

A shifting fish stock aggravates existing fisheries challenges because it contravenes the “clear boundaries” principle for sustainable governance of common pool resources, eroding incentives for conservation when new free riders gain access to a resource (4, 5). Stock shifts can incentivize regional overharvesting as actors scramble to exploit a

perceived disappearing resource. Similarly, a stock that moves to straddle national boundaries may find itself in “double jeopardy,” exposed to unsustainable competitive harvesting (5). The governance challenges posed by shifting marine animal distributions have been recognized in certain cases, but the scope and magnitude of this problem has remained unclear and there have been few efforts to address the issues.

## Shifting fishes already caused conflict

International law recognizes that cooperation is necessary for the management of shared stocks, yet fisheries disputes remain commonplace. In fact, fisheries—alongside maritime boundaries and other resources—are a leading cause of militarized disputes between democratic states in the post-WWII period (6).

The so-called ‘mackerel war’ erupted in 2007 when the northeast Atlantic Mackerel stock (*Scomber scombrus*)—a fishery then managed by the European Union, Norway, and Faroe Islands—shifted into Iceland’s Exclusive Economic Zone (EEZ) (7). Conflict erupted over appropriate allocations among the actors, compounded by disagreement about the drivers and therefore the expected duration of the shift. In the absence of cooperation, the mackerel stock became increasingly overfished (7).

Shifting species have caused conflict even between countries that historically cooperate closely. During a warm period in the 1980s and 1990s, United States catches of Pacific salmon (*Oncorhynchus* spp.) increased more than ten-fold and included increased interceptions of Canadian-bound salmon (5). Canadian fisheries retaliated by targeting salmon migrating to spawn in the USA. Six years of rancorous disagreement passed before a new joint management agreement was concluded.

Shifting species distributions also present internal challenges for nations. Blueline tilefish (*Caulolatilus microps*) were historically caught and managed south of the Virginia-North Carolina border, USA. When tilefish appeared further north, a fishery

exploited the stock for nearly a decade without regulation. This situation only changed in 2015 with emergency rules from the National Marine Fisheries Service.

These cases exemplify a general pattern: existing fisheries management and governance is largely predicated on population geographies that remain broadly static through time. Challenges emerge when stock distributions become less predictable and are compounded when states act unilaterally to exploit the resultant windfall.

## The magnitude of future challenges

The oceans have already absorbed 93% of the heat from climate change (8), and if future species geographic shifts exceed historical variation, adjustment to existing ocean governance will be needed. Alternatively, future geographic shifts could be sufficiently limited to retain stocks primarily under the jurisdiction of those countries currently managing them. The extent to which future shifts in species distributions will generate newly shared fish stocks and increase the potential for conflict, however, has not been clear.

We therefore examined future shifts in the distribution of 892 commercially important marine fish and invertebrates in relation to the world’s EEZs (see Supplementary Materials). Instead of precisely forecasting future changes, the projections help delineate plausible scenarios that illustrate the extent of future challenges. Comparing 1950-2014 against 2090-2100, we found that many of the world’s EEZs are likely to receive one to five new, climate-driven transboundary stocks by the end of the century (Fig. 1A). Up to ten new stocks were projected for some EEZs in east Asia, a region where new transboundary stocks could exacerbate maritime relations already complicated by disputed territories, overlapping EEZ claims, and illegal fishing.

The number of EEZs with new transboundary stocks was expected to reach 46±8 (±standard error) or 60±4 by 2060 (57±4 or 85±22 by 2080) under strong mitigation (Representative Concentration

<sup>1</sup>Dept. of Ecology, Evolution, and Natural Resources, Rutgers University, New Brunswick, NJ, USA.

<sup>2</sup>malin.pinsky@rutgers.edu.

<sup>3</sup>Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada.

<sup>4</sup>reygondeau@oceans.ubc.ca, j.palacios@oceans.ubc.ca, and w.cheung@oceans.ubc.ca.

<sup>5</sup>Netherlands Institute for the Law of the Sea, Utrecht University, Utrecht, Netherlands.

<sup>6</sup>School of Law and Politics, Cardiff University, UK. riddellr@cardiff.ac.uk.

<sup>7</sup>Stockholm Resilience Center, Stockholm University, Stockholm, Sweden. jessica.spijkers@su.se.

<sup>8</sup>Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University, Queensland, Australia.

\*malin.pinsky@rutgers.edu

1 Pathway [RCP] 2.6) or business-as-usual  
2 (RCP 8.5) greenhouse gas emissions  
3 scenarios, respectively (Fig. 1B). Limiting  
4 greenhouse gas emissions would therefore  
5 reduce the potential for new fisheries  
6 conflicts. In total, new transboundary stocks  
7 were projected to be present in 23% (RCP  
8 2.6) to 35% (RCP 8.5) of global EEZs by 2100  
9 (Fig. 1A and 1B). In the tropics, fisheries will  
10 likely move out but not in, a process that  
11 creates additional food security concerns.

12 Most countries were projected to receive  
13 1-30% of their potential fisheries catch from  
14 new stocks by 2100, but percentages were  
15 higher in temperate regions (e.g., Australia  
16 or countries around the Baltic and Bering  
17 Seas) and highest in shared Antarctic fishing  
18 grounds (92%). We note that past conflicts  
19 over even a single species with low catch  
20 volumes have been significant.

### 21 **Current governance frameworks** 22 **have major gaps**

23 The current legal framework for the  
24 international regulation of fisheries does not  
25 directly account for fluctuating or changing  
26 distributions. The primary source of  
27 international obligations for the governance  
28 of global fisheries resources remains the UN  
29 Convention on the Law of the Sea 1982  
30 (UNCLOS) which entered into force in 1994.  
31 Under UNCLOS, states must ensure that  
32 fisheries in their EEZs are not endangered by  
33 overexploitation; hence national regulations  
34 for fishing could provide a basis for far-  
35 sighted management of shifting stocks.

36 For “straddling stocks” occurring in two  
37 or more EEZs, or within an EEZ and the high  
38 seas, UNCLOS obliges states to cooperate to  
39 establish necessary conservation and  
40 management measures. In 1995, the  
41 fisheries regime of UNCLOS was buttressed  
42 by the UN Fish Stocks Agreement (UNFSA),  
43 which specifically applies to straddling and  
44 highly migratory stocks and entered into  
45 force in 2001. The UNFSA reinforced  
46 national obligations to cooperate and to  
47 apply a precautionary approach to fisheries.  
48 Notwithstanding its constructive influence  
49 on international fisheries law, the UNFSA has  
50 not focused attention upon shifting stocks.

51 Regional fisheries management  
52 organizations (RFMOs) remain the primary  
53 vehicle through which straddling fish stocks  
54 are managed. Many RFMOs address single  
55 species such as tuna or salmon, however,  
56 and an influx of additional species lies  
57 beyond their individual remits. Despite  
58 recent progress, fish stocks in large parts of  
59 the global oceans are weakly managed—a  
trend that may be exacerbated by shifting  
distributions. Few bodies have established a

clear position on the elaboration of  
regulations for new fisheries, a loophole that  
often allows newly fished stocks to be  
heavily exploited before meaningful  
standards are developed (9). Moreover,  
there has been little to no cooperation  
between RFMOs on the potential for future  
shared stocks, and limited interactions with  
other regional and sectoral regulators.  
Concerns also remain over the limited  
application of ecosystem-based  
management principles by RFMOs, including  
limited consideration of impacts on non-  
focal species.

Attempts to resolve conflicts judicially  
are largely untested, although shifting stocks  
could prompt judicial consideration in the  
future (legal processes in the mackerel  
dispute were discontinued by the  
contending parties). International courts and  
tribunals have been receptive to calls for  
more responsible stewardship of fish stocks  
and have adopted far-sighted allocation  
practices in individual cases. Nevertheless,  
they have historically accorded little  
consideration to environmental factors  
(climate or otherwise) in resolving territorial  
disputes, and shifting stocks have not played  
an overt role in boundary decisions to date.  
Likewise, there is little scope to revise  
jurisdictional entitlements in response to  
changing marine circumstances. Ultimately,  
it is also important to recognize that judicial  
decisions do not always resolve conflicts:  
China refused to participate in recent  
arbitration concerning the South China Sea,  
rendering fisheries relations unpredictable  
and vulnerable to unilateral actions around  
stock shifts in this region.

### 40 **Governance solutions for shifting fish**

Experience from past conflicts, the  
projected widespread emergence of new  
transboundary stocks, and the gaps in  
current governance frameworks all suggest  
that substantial new approaches are needed  
to forestall future conflict. The first step is  
for management authorities to plan ahead for  
cooperative management, which demands  
an emphasis on reliable projections of  
species shifts and of associated uncertainties.  
Negotiations over shared stocks are easier  
with mutually-agreed facts, which can be  
facilitated by data from multilateral or  
independent scientific bodies, notably the  
Intergovernmental Panel on Climate Change  
(IPCC). All projections should be interpreted  
cautiously, however, given the high potential  
for abrupt thresholds and surprises in  
ecological systems. These inherent  
uncertainties complicate localized  
evaluations of the costs and benefits of

cooperation (10, 11).

For RFMOs, performance reviews  
provide an established process for such  
considerations, although success depends on  
capacity and a culture of critical reflection.  
Data-sharing with other bodies is also vital.  
The Commission for the Conservation of  
Antarctic Marine Living Resources  
(CCAMLR) has been exemplary in this regard  
and has established collaborative  
arrangements with neighboring RFMOs to  
monitor the movement of stocks across  
regulatory frontiers. Crucially, CCAMLR has  
forged similar arrangements with other  
sectoral regulators to consider the  
prospective ecological footprint of a moving  
fishing industry.

Cooperation must then extend beyond  
data-sharing to inform genuinely  
collaborative management where necessary.  
For example, to meet their responsibilities  
under UNCLOS and UNFSA, RFMOs must  
accept the prospect of shared oversight and  
agree on regulatory responsibilities for  
species with an increasing presence in  
neighboring areas. Overlapping stocks have  
already generated tensions, exemplified in  
the 1990s between the Northwest Atlantic  
Fisheries Organization (NAFO) and the  
North East Atlantic Fisheries Commission  
(NEAFC) until shared responsibilities were  
implemented. CCAMLR has taken a different  
and more constructive approach to  
cooperation, in part by imposing greater  
precautionary oversight of new fisheries,  
including for tuna displaced by ocean  
warming (9). Data-sharing and appropriate  
co-management can further inform other  
vital regulatory approaches, including area-  
based management tools and no-take zones  
to reduce pressure on shifting stocks. RFMOs  
have proved adept at implementing  
precautionary oversight for emerging  
fisheries, based on strict catch limits, prior  
approval and a graduated exploitation of  
previously unfished areas and species (9).

Prevailing management mentalities also  
remain a fundamental challenge, notably the  
perception that one party “wins” and the  
other “loses” when a stock shifts  
geographically, an asymmetry that can  
undermine cooperation (12). Game theory  
provides inviting lessons for incentivizing  
cooperation, including broadening the scope  
of negotiations to include non-fish resources  
(5), albeit at the risk of reducing fisheries to a  
mere bargaining chip as suggested by the  
Brexite negotiations. In the case of the US-  
Canada Pacific Salmon Treaty, however,  
contributions to a conservation fund helped  
stabilize relations, creating an alternative

avenue for compensation often termed a “side payment” (13). Similar approaches are illustrated by Norway and Russia swapping fisheries access within EEZs to balance shifts in shared stocks, an important example of flexibility in co-managing Arctic resources. Trading herring, blue whiting, or other fishery access to help resolve the Icelandic mackerel dispute has also been suggested (14). The value of side-payments suggests that new bilateral or multilateral agreements concerning shifting fisheries will be more effective if negotiated at higher political levels. Presently, however, multilateral processes generally focus on discrete issues to help secure widespread support. For instance, it is being actively debated whether fisheries should be included or excluded from ongoing United Nations negotiations on the conservation and sustainable use of marine biodiversity beyond national jurisdiction (BBNJ), despite this process expressly seeking further integration across sectors of marine governance.

Compounding this proprietorial approach are concerns that access to current and prospective RFMOs is restricted to those with a “real interest” in the stock, with participatory rights zealously guarded by current constituents (14, 15). The North Atlantic RFMOs, which are facing geographic shifts in a number of important fisheries, are currently closed to new members (9, 15). Many existing fisheries are based on principles of zonal attachment and relative stability, with national allocations reliant upon historical presence. A first step towards more adaptable fisheries would be objective and regularly updated allocations of catch or effort to reflect changes in stock distributions. An intriguing, alternative approach would be to develop fisheries permits that are tradeable across political boundaries, as considered to some extent by the International Commission for the Conservation of Atlantic Tunas (ICCAT) and by NAFO (15). Regions with disputed maritime boundaries will remain especially prone to conflict, and shifting stocks may require additional consideration in the boundary delimitation process or bespoke arrangements between states over contested resources.

Climate-driven shifts in marine species distributions represent a growing governance issue affecting states in all regions of the world. An alternative future of widespread non-cooperative management over new transboundary stocks risks extensive overfishing, decline in global food

and livelihood provisioning from the ocean, fractured international relationships, and political conflicts that could spill over into other, non-fishery areas of international politics. However, the challenges can be mitigated through far-sighted governance strategies. With adaptable agreements between states, we have hope that ocean fisheries can continue to provide the myriad nutritional, livelihood, and economic opportunities relied upon by billions of people around the world.

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List of Supplementary Materials and Methods

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**Fig. 1. Ocean warming will drive the appearance of new transboundary fisheries around the world.** (A) Map highlights Exclusive Economic Zones (EEZs) projected to contain one or more new fishery stocks by 2100, as compared to the distribution of fish stocks in 1950-2014. The projections represent an ensemble average across three earth system models under the high greenhouse gas emissions scenario (RCP 8.5). (B) The number of EEZs with new transboundary stocks increased approximately linearly with increases in global temperature. The extent of warming and number of EEZs were greater under a high greenhouse gas emissions scenario (RCP 8.5, red), and lower under a low emissions scenario (RCP 2.6, blue). The thin lines are projections from each of three earth system models, while the thick lines represent the average across models.