ENHANCING STUDENTS CRITICAL THINKING ABOUT MARINE POLLUTION USING SCIENTIFICALLY-BASED SCENARIOS

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SUMMARY: Marine pollution is threatening the world's seas, caused primarily by anthropogenic activities both on and off shore (oil spills, plastics, chemicals, etc.). The environmental damage from a large disaster like an oil spill, can be catastrophic in itself, affecting both marine life and human health. Floating debris causes additional problems by accumulating in the food chain and eventually being consumed also by humans. A key part of the solution to this complex problem is a strong environmental awareness of the impact and costs of marine pollution. This will occur by changing people's attitudes, starting from a young age. The Sea4All project aims to significantly contribute to the awareness and consciousness of school children and educational institutions using innovative Information Communication Technologies (ICT), such as multilevel game-based learning tools and e-learning platforms. This will be achieve through the development of scientifically-based scenarios, simplified to the needs of the target groups. By increasing awareness through theSea4All program, potential strategies addressing the problem of marine pollution could arise.

1. INTRODUCTION

Marine and coastal environments are an extremely valuable part of our planet and are being negatively affected by human activities, such as marine traffic, fisheries, urbanization, tourism and offshore oil

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exploitation. For the past few decades, marine ecosystems have faced increasing anthropogenic threats, including pollution from onshore and off shore activities and major disasters including oil spills and chemicals spills. The most prominent man-made pollutants that reach the sea are: pesticides, herbicides, chemical fertilizers, detergents, oil, sewage, plastics and other solids. The damage caused to the environment by these pollutants is significant and has an impact on both marine life and public health of coastal communities. Undoubtedly, the targeted training and education of young people on the protection of the marine environment can be a powerful tool, without excluding the fact that people of all ages and education levels should be aware of marine pollution issues.

Scientifically based scenarios concerning the integrated treatment of small oil spills (Alves et al., 2014) and floating plastic debris (Steen et al., 2016), contribute significantly to the training and education of young people and teachers. These stakeholders will be informed using simplified approximations regarding the fate of small-scale oil spills and harmful floating debris, giving special emphasis on coastal ecosystems and marine trophic webs. Specifically, the development of scientifically-based scenarios for the Sea4All project will focus on the following topics: 1. How oil spills and floating debris reach our seas; 2. Which factors affect the dispersion of oil spills and floating debris; 3. What happens to oil and floating debris on the sea surface; 4. How oil and floating debris act in water; 5. What is the behavior of oil on various beach sediments and rocks; 6. What is the rate of breakdown of the various types of marine debris and in which ways are they incorporated into the marine food chain inevitably leading to humans; 7. Who responds to oil spills and floating debris, and what are the best techniques to manage these problems; 8. How can each one of us, as a citizen, develop or be part of initiatives and actions that combat marine pollution, and at the same time raise awareness about this worsening problem.

The aim of the Sea4All project (https://www.sea4all-project.eu/) is to promote new technologies and innovative methods as well as to develop novel learning materials and tools under the general topic of "combating marine pollution", to enhance knowledge acquisition and skill development in education.

2. METHODOLY

The methodology used to develop scientifically-based scenarios can be broken down into three categories: shoreline geology and seabed morphology, meteorological, oceanographic status, pollution simulations and marine ecology issues. Shoreline geology and seabed morphology will be assessed through the mapping of the coastal geological formations. Bathymetric maps will be analyzed from combined sources, such as international database and nautical maps to identify and interpret bathymetric features. Additionally, shoreline susceptibility will be estimated in selected coastal areas using the Environmental Sensitivity Index (ESI).

Meteorological and oceanographic status and pollution simulations will be undertaken using GNOME (version 1.3.10, Beegle-Krause, 2001) and ADIOS (version 2.0.12, Lehr, 2008) software. Specifically, through the use of atmospheric, oceanographic, sea state forecasting results and satellite data (where appropriate) for areas selected from various databases. For the purpose of visualization, data processing will take into account the structure and format of the atmospheric, oceanographic and sea state forecasting results. Data interpretation, of all datasets in the form of information layers integrated in a database, can depict interactions among all parameters of interest and the fate of the pollutants will be modelled. From this, response methods and mitigation techniques will be suggested.

Marine ecology issues will be assessed through determining the impacts of oil spills and floating debris to marine organisms, such as how different types of marine animals (e.g. fish, marine mammals, seabirds) are influenced and what are the long-term effects and impacts associated with human consumption of seafood from the impacted areas. Various methods and rates of breakdown of different types of marine debris into smaller particles (fibers, fragments, pellets) and processes in which they are incorporated into marine food chain will be examined, as well as the distribution of contaminants from oil spills, under the influence of sea currents and products of marine debris breakdown through marine ecosystems. Products of contaminant breakdown from oil spills and marine debris into the marine ecosystem will be assessed, such as the incorporation into marine organisms (e.g. fish) and into the marine ecosystem (e.g. trapped in marine sediments).

3. RESULTS AND DISCUSSION

As this project is currently in the preliminary stages of development, the results have not been collected. Therefore, this is a discussion on the anticipated results. Shoreline geology (Fig. 1) and seabed morphology (Figs. 2 and 3) are the first steps in the methodology provided in the context of the Sea4All project. It is extremely important to be aware of the exact composition and structure of impacted coasts because their characteristics are related to the potential effects of oil and floating debris on the shoreline. For example, oil and leakages from decomposed litter flow downward into the sand, altering the balance of coastal ecosystems. Moreover, coastal seabed morphology is strongly related to the movement of sea currents that are able to transport nutrients, terrigenous sediments, anthropogenic pollutants, litter and further affect sediment deposition. Detailed bathymetry, based on the processing of bathymetric data from EMODNET (Berthou et al., 2008), and recent developed algorithms to analyze the seabed morphology (Panagiotakis and Kokinou, 2014; 2015; 2017) can extract valuable information for environmental studies. The southern Cretan offshore generally reveals depths ranging between 250m and 4500m (Fig. 2). Slopes (Fig. 3) of the wide area offshore southern Crete are generally steep, exceeding 60°, with a few exceptions of gentle slopes (0º-20º) along the thin coastal strip of the southern Cretan margin and along the main axis of the Ptolemy and Pliny troughs. The presence of large slopes around Gavdos Rise, and the gentle slopes along the coastal strip of the southwest Cretan margin (Fig. 3), affect the movement of sea currents and suffer the aforementioned consequences.

(a) (b)

Figure 1. Coastal geological formations in (a) Cavo Greco (SE Cyprus) and (b) Falasarna (W Crete).

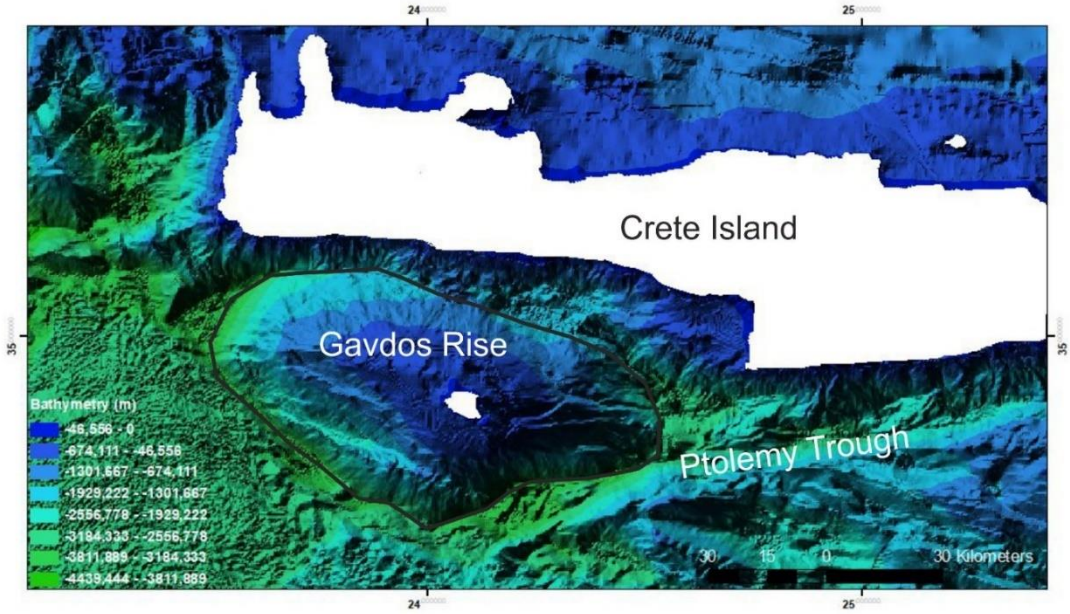


Figure 2. Detailed bathymetry based on the processing of bathymetric data from EMODNET (Berthou et al., 2008). Onshore areas are indicated in white. Main morphological units below sea level are the Gavdos Rise and the Prolemy Trough.

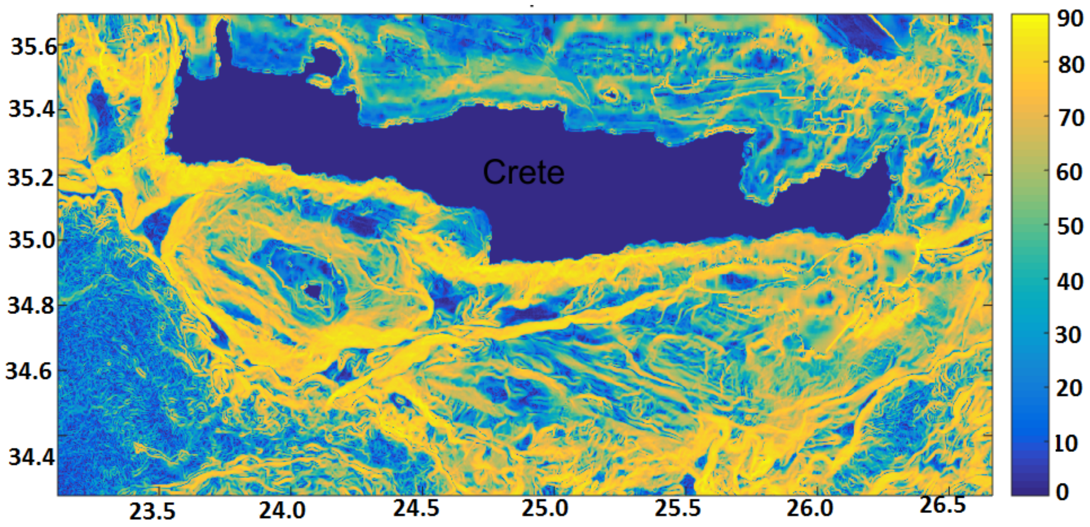


Figure 3. The seabed slopes (o) around Crete Island (Greece).

Following Adler and Inbar (2007), The ESI uses shoreline geology and seabed morphology in its evaluation process. For example, the shoreline at Agios Pavlos in South Crete, where vertical rock cliffs are observed, are impermeable to oil, therefore exhibiting a high natural cleanup ability (Fig. 4). Such vertical rocks also prevent pollution from floating debris. Conversely, the shoreline in the Tympaki Gulf (between Agia Galini and Kaloi Limenes) is characterized by flat wave-cut platforms, exposed to potential oil washing onshore, and consist of both coarse-grain sands and pebble beaches. Part of the Chania shoreline presents an ESI 5B susceptibility index, having limited natural clean up ability (Alves et al., 2014), showing irregular protrusions of rocks and boulders alternating with unconsolidated sediment. This complex shoreline morphology creates oil traps in shoreline indentations and pools, showing medium to high penetration of oil.

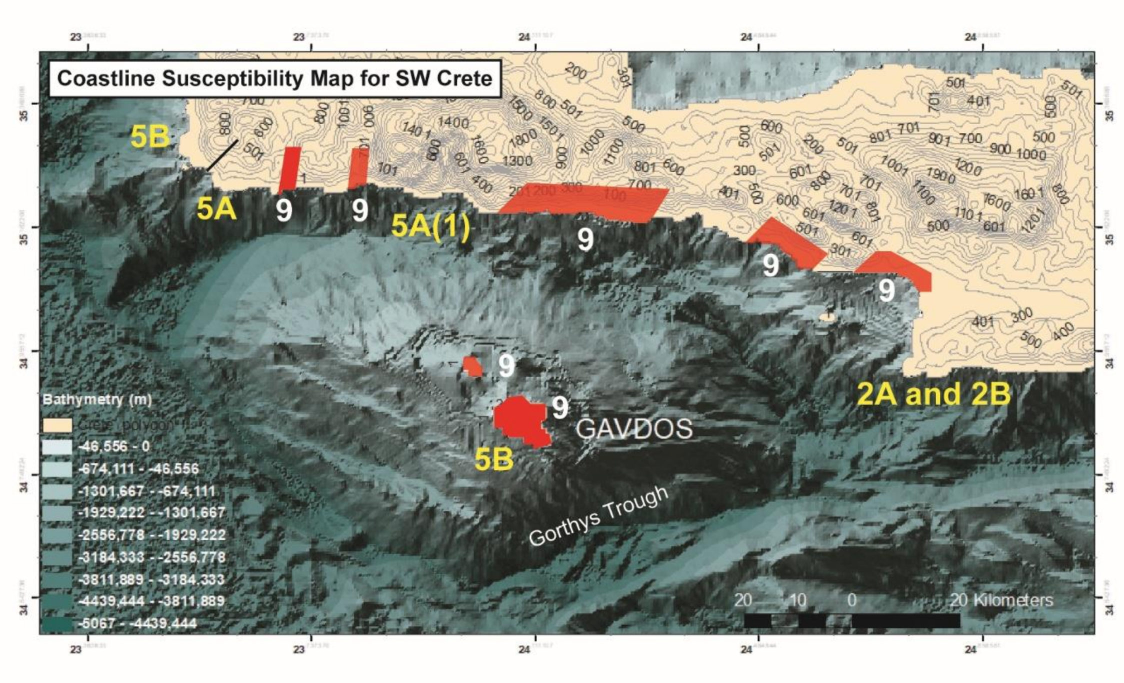


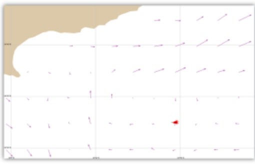
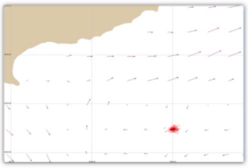
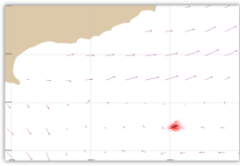
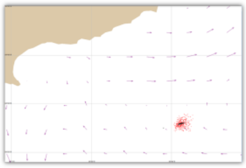
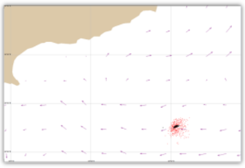
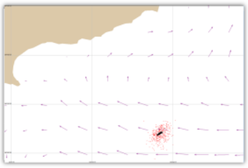
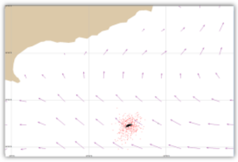
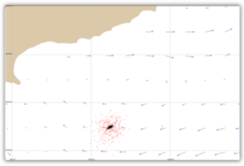
Figure 4. Coastline susceptibility (ESI) for southwestern Crete. 1 to 9 - Adler and Inbar (2007) Environmental Susceptibility Classification specifically applied to plastic pollution.

Table 1 shows the fate of an oil spill occurring near Limassol Port, in Cyprus, due to a ship collision (position LAT: 34o 25N; LON: 33o 38E) on the 25 March 2018 at 02:00 UTC. The flow rate of the oil into the sea was estimated to be 200 metric tons of fuel oil (API: 12.3). An instantaneous spill was considered in the simulations for a period of 45 hours. Since the ship cargo was dominantly composed of plastic material, debris appeared floating on the sea surface. In the simulations produced, the initial location of the spill is indicated by a small cross, "+". With the aid of the Automated Data Inquiry for Oil Spills (Lehr, 2008, ADIOS, version 2.0.12) and of the General NOAA Operational Modeling Environment software applications (Beegle-Krause, 2001, GNOME, version 1.3.10), reliable simulations of oil spill and floating debris expansion can be highlighted.

Figure 5 presents the remaining oil and debris particles that constitute 14% of the total released amount, while 7% was evaporated and 79% dispersed after 41 hours. In this model simulation, the oil spill and debris did not reach the coast. The accuracy of the trajectory predictions depends on the influence of uncertainty in the information given (Galt et al., 1996). In trajectory modeling, even the best-available information on forecast winds and currents can often contain errors because winds and currents cannot be entirely predictable. It is rare for wind speed and direction forecasts to be accurate and precise. Even harder is to accurately predict current patterns. Since it is known that available wind and current information is, to a degree, uncertain, it is necessary to calculate not only the best trajectory prediction, but also the associated error estimates.

Despite their great tourism and economic significance, the coasts of the Mediterranean Sea are greatly impacted by floating marine debris. Even in countries like Greece, where tourism generates over €35 billion to the country's GDP, their economic significance has not been an adequate incentive to manage marine litter pollution. Plastic debris floating in the sea (Figs. 6a, b) causes direct or indirect mortality to a large number of marine species. Numerous types of plastics break down in a few months' time and rapidly enter the food chain, to aggregate as fibers or particles in an organism's digestive system, especially in species belonging to higher trophic levels. Effects on human health are certain but not yet quantified. After an oil spill, the oil breaks down into hundreds of different substances, each type having a different fate in the marine ecosystems. Some evaporate into the atmosphere, others are dispersed within the water column and travel further, propelled by sea currents, whereas the heavier components either are washed to the shore (Fig. 6c, d) or sink to the sea floor, as seen a few days after the oil spill of Agia Zoni II in September 2017 (in the region of Attika-Salamina in Greece). Therefore, different toxic compounds enter the food chain through various pathways and can remain *in situ* for many decades.

Table 1. Oil and debris spill scenario evolution (Beegle-Krause, 2001, GNOME, version 1.3.10) of the case concerning a ship collision near Limassol Port (Cyprus). Red spots designate debris, while black spots show the oil particles.

			
Oil spill after 3 hours (25/03/2018 05:00 UTC). The remaining particles constitute 86% of the total released amount, while 4% was evaporated and 11% dispersed.	Oil spill after 7 hours (25/03/2018 9:00 UTC). The remaining particles constitute 67% of the total released amount, while 5% was evaporated and 27% dispersed.	Oil spill after 11 hours (25/03/2018 13:00 UTC). The remaining particles constitute 54% of the total released amount, while 6% was evaporated and 40% dispersed.	Oil spill after 17 hours (25/03/2018 19:00 UTC). The remaining particles constitute 40% of the total released amount, while 6% was evaporated and 54% dispersed.
			
Oil spill after 23 hours (26/03/2018 01:00 UTC). The remaining particles constitute 30% of the total released amount, while 6% was evaporated and 63% dispersed.	Oil spill after 29 hours (26/03/2018 07:00 UTC). The remaining particles constitute 23% of the total released amount, while 7% was evaporated and 71% dispersed.	Oil spill after 35 hours (26/03/2018 13:00 UTC). The remaining oil constitute 18% of the total released amount, while 7% was evaporated and 76% dispersed.	Oil spill after 41 hours (26/03/2018 19:00 UTC). The remaining particles constitute 14% of the total released amount, while 7% was evaporated and 79% dispersed.

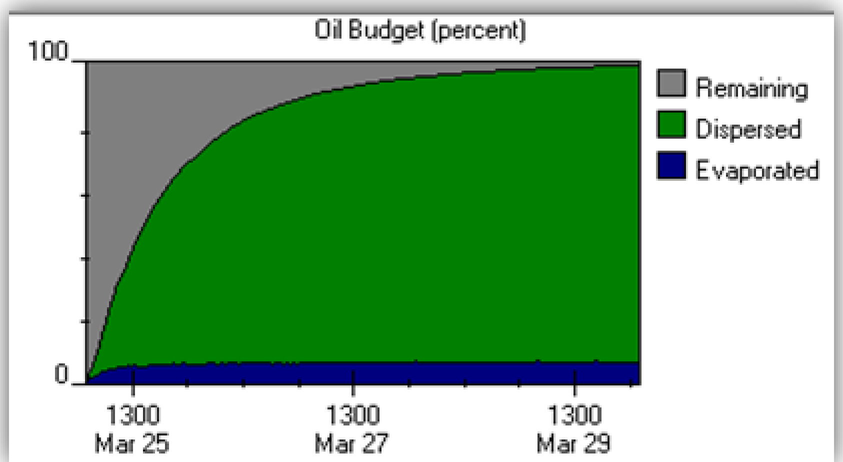
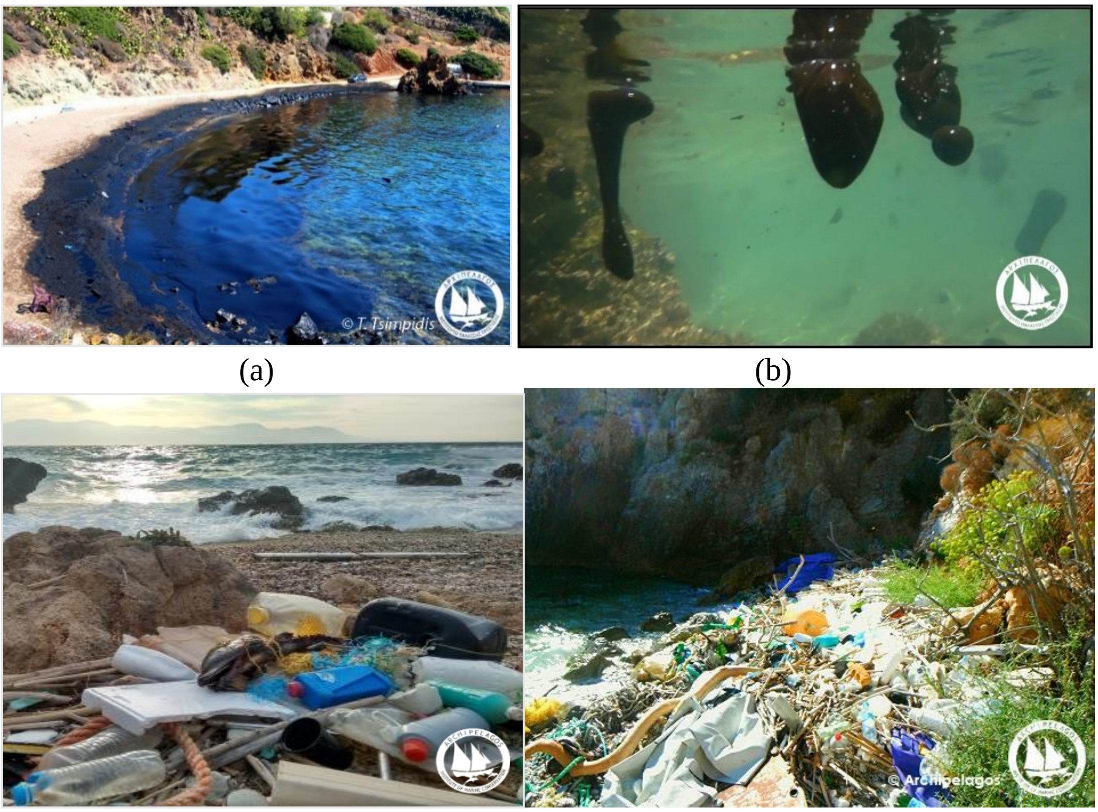


Figure 5. Oil/debris spill fate after 45 hours (Lehr, 2008, ADIOS, version 2.0.12).



(a) (b) (c) (d)

Figure 6. Oil spills (a, b) and floating debris (c, d) severely degrade the coastal environment.

4. CONCLUSIONS

In conclusion, critical thinking should be fostered in school children and younger generations to promote the problem marine pollution and generate new strategies to solve it. There will always be areas of higher susceptibility and hazard in case of an acute pollution event, even with the best mitigation techniques in practice. For that reason, pupils, educators and civil populations should:

(1) be aware of bathymetric, geomorphological, geological and oceanographic parameters influencing the movement of marine pollution, and understand them as key parameters controlling the dispersion of such pollution;

(2) understand that behavioural changes are paramount to control and ultimately avoid pollution events;

(3) understand that the best practice and techniques should be divulged at a higher level, in schools and in events associated with the marine realm.

In order to better predict the potential threats of a disaster, such as an oil spill, or marine floating debris and plastic litter, simulations obtained by software applications can be very helpful. GNOME and ADIOS applications, can provide information regarding how winds, currents and other processes might move and spread oil spilled on the water, how predicted oil trajectories are affected by uncertainty in current and wind observations and forecasts, and how spilled oil is predicted to change chemically and physically during the time that it remains on the water surface. These scientific tools are helpful in relation to real accidents but also as a pedagogical aid, will help students and the public to better understand the consequences of environmental disasters in a pragmatic manner.

Such an effort should focus on areas of intense urbanization, environmentally sensitive areas, regions with important industry, shipping or tourism, as these require specific actions to manage marine pollution. Many of these pollution events are seasonal based on tourism, for instance, close to the largest tourist areas of Crete and Cyprus. In the models presented here, a final key factor to consider is that oceanographic and meteorological conditions can maintain marine pollution in the open sea for long periods of time. In such cases, pollutants can be assimilated by living organisms, impacting he food chain and negatively affecting the coastal populations many months or years after the pollution event. Therefore, it is essential to closely monitor the conditions leading to the release of pollutants.

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REFERENCES

Adler, E. & Inbar, M., 2007, Shoreline sensitivity to oil spills, the Mediterranean coast of Israel: Assessment and analysis. Ocean & Coast. Manag., 50, 24–34.

Alves, T.M., Kokinou, E. &Zodiatis, G., 2014, A three-step model to assess shoreline and offshore susceptibility to oil spills: The south Aegean (Crete) as an analogue for confined marine basins. Marine Pollution Bulletin, 86(1-2), 443-457.

Beegle-Krause, J., 2001, General NOAA Oil Modeling Environment (Gnome): A New Spill Trajectory Model. International Oil Spill Conference Proceedings, 2, 865–871.

Berthou, P. et al., 2008, EMODNET-the European marine observation and data network. European Science Foundation– Marine Board, 10.

Galt, J.A., Payton, D.L., Norris, H. & Friel C., 1996, Digital Distribution Standard for NOAA Trajectory Analysis Information. ERD (formerly HAZMAT) Report 96-4. Seattle: NOAA Emergency Response Division (formerly Hazardous Materials Response and Assessment Division), 43 pp.

Lehr, W.J., 2008, The Potential Use of Small UAS in Spill Response." International Oil Spill Conference Proceedings, 1, 431–433.

Panagiotakis, C., &Kokinou, E., 2014, Automatic enhancement and detection of active sea faults from bathymetry. Proceedings of the 22nd International Conference on Pattern Recognition (ICPR), IEEE, 855-860.

Panagiotakis, C., &Kokinou, E., 2015, Linear Pattern Detection of Geological Faults via a Topology and Shape Optimization Method. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 8(1), 3-11.

Panagiotakis, C., &Kokinou, E., 2017, Unsupervised Detection of Topographic Highs with Arbitrary Basal Shapes Based on Volume Evolution of Isocontours. Computers and Geosciences, 102, 22-33.

Steen, R., Torjussen, C.S., Jones, D.W., Tsimpidis, T. &Miliou, A., 2016, Plastic mistaken for prey by a colony-breeding Eleonora's falcon (Falco eleonorae) in the Mediterranean Sea, revealed by camera-trap. Marine Pollution Bulletin, 106(1–2), 200-201.