Chapter 12
A Marine Spatial Planning Approach to Minimize Discards: Challenges and Opportunities of the Landing Obligation in European Waters

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Abstract A sensible approach to minimize discards is to avoid areas or seasons where unwanted catch may be present. The implementation of a Marine Spatial Planning (MSP) approach to discard management requires the understanding of marine biological processes, as well as fishing conditions at a defined spatial scale. Mathematical models that analyze the spatio-temporal conditions of selected fishing areas allow the definition of different scenarios where discards are minimized by avoiding fishing for unwanted species and/or illegal specimens. Here we show some examples of how particular spatial models can be used for advice on MSP for discards. We introduce a geoserver GIS platform developed to produce maps of discard probability by using a Fishing Suitable Index. We also give an example of simulating virtual fishing closures. The inclusion of a Marine Spatial Planning approach to implement the Landing Obligation will bring some new challenges and opportunities. Finally, we will discuss and suggest some recommendations for its effective and successful implementation.

Keywords Discards GIS platform · Landing obligation · Maps of discard probability · Marine spatial planning · Simulating fishing closures

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12.1 Introduction

The FAO Fisheries Glossary describes discards as

> "*the proportion of the total organic material of animal origin in the catch, which is thrown away or dumped at sea, for whatever reason. It does not include plant material and post-harvest waste such as offal*".

Additionally, FAO also defines bycatch as

> "the part of a catch of a fishing unit taken incidentally in addition to the target species towards which fishing effort is directed. Some or all of it may be returned to the sea as discards."

The discards may be dead or alive, depending on the selectivity of the fishing gear and the injuries and stress suffered by fishing. Although some species have high survival chances, many of the discards are dead or dying when rejected.

The "discards problem" is a key point in fisheries management around the world (Karp et al., this volume). It is not an easy issue, as it occurs at the core of fishing operations, both from economic, legal and biological points of view. It is basically a decision-making process, i.e. the decision to reject or retain a fish. However, there is usually a common perception from all sides (the public, NGOs, fishing sectors, policymakers, scientists, etc.) that discards are generally negative and that a better solution should be found.

Discarding unwanted catches has many assumed negative environmental and economic effects, especially since very few discarded fish will actually survive. Some of these effects are summarized below:

- Discarding juveniles means lower future catch opportunities and reduced spawning biomass.
- Discarding mature individuals weakens the stock's productivity both in the short and long term.
- Discarding fish, crustaceans, sea birds, sea mammals and non-targeted species undermines the balance of the marine ecosystem.
- Some vulnerable species can become severely depleted even in the absence of any directed fishery (e.g., certain sharks and rays).
- For fishers, discarding is a waste of time and effort in the present, as well as a serious potential loss of future income.

The European Union has recently reformed the Common Fishery Policy (CFP; EU 2013). One of the most important changes in the new CFP is the focus on what is caught rather than what is landed, as well as the introduction of a Landing Obligation, which has been progressively implemented. It is expected that full enforcement of the Landing Obligation will have a direct impact on discard reduction through more responsible and selective fishing.

On the other hand, Marine Spatial Planning (MSP) is also related to the implementation of the Landing Obligation. Fisheries management needs to consider the spatial dynamics where the natural stocks and fleet interact. Life always occurs in a defined space and time and fishing exploits marine living resources. For instance, a sensible approach to minimize discards is to simply avoid areas or seasons where unwanted catch is more likely (O'Keefe et al. 2013; Vilela et al. 2015; Paradinas et al. 2016).

The implementation of a Marine Spatial Planning approach to discard management requires the understanding of marine biological processes, as well as fishing conditions at a defined spatial scale. However, quantifying the fishery importance in an area is a challenging task because of a lack of information due to the inherent constrains of sampling at sea. Mathematical models that analyze the spatio-temporal conditions of considered fishing areas allow the definition of different scenarios of the fishing activity where discards are minimized by avoiding fishing undesirable species and/or illegal specimens (Hobday and Hartmann 2006; Pennino et al. 2014).

Here we show some examples of how particular spatial models can be used for advice on MSP for discards. We introduce a geoserver GIS platform developed to produce maps of discard probability by using a Fishing Suitable Index. This platform is designed to help fishers locate areas where they can maximize yield while minimizing unwanted catch. We also provide an example of simulating virtual fishing closures. This was done to test different possibilities of spatial planning for a purse seine fishery off the Southern Spanish Mediterranean coast.

The inclusion of a Marine Spatial Planning approach to implement the Landing Obligation will bring some new challenges and opportunities. Finally, we discuss and suggest some recommendations for its effective and successful implementation. We conclude that the Landing Obligation should be accompanied by other measures such as improvements in controlling fishing effort, better fishing selectivity, spatio-temporal fishing restrictions for vulnerable sizes and/or areas, effective enforcement and finally the agreement, commitment and support from the fishing sector to comply with the rules and regulations.

12.2 Marine Spatial Planning Approach to Minimize Discards

MSP aims to manage the different and shared uses in a marine area. This is typically referred to as "Ecosystem services", defined according to Wikipedia as *"the many and varied benefits that humans freely gain from the natural environment and from properly-functioning ecosystems"* (https://en.wikipedia.org/wiki/Ecosystem_services.)

Marine Spatial Planning is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that usually have been specified through a political process (http://msp.ioc-unesco.org/about/marine-spatial-planning/). It is important to note that MSP is not only conservation planning, although it considers environmental protection and the sustainability of the marine environment for future generations as one of its main objectives. MSP seeks to balance economic development and environmental conservation, and not focus only on the goals of conservation or protection. Additionally, characteristics of Marine Spatial Planning also include ecosystem-based, area-based, integrated, adaptive, strategic, and participatory procedures.

The concept of multi-uses MSP is a relatively new approach to marine management. Actually, the first MSP workshop was held by UNESCO in 2006 in Paris, which makes this a recent movement considering the slow inertia and complexity to develop, establish and implement such a management system. However, since the beginning of its formulation there has been worldwide agreement on the need for such an approach. There are thus already a number of MSP applications in various regions (Maxwell et al. 2015; Pennino et al. 2017).

Although it varies greatly between countries, we may find many different uses of marine areas in Europe. This includes:

1. Extraction of non-renewable and renewable resources, including aquaculture.
2. Transit of people and merchandise, which are ruled by both national and international law.
3. Coastal zones are areas of residence and enjoyment.
4. Areas subject to new uses in the future, such as renewable energies, new methods for extraction of minerals, oils, new fishing grounds, etc.

This shared use can cause conflicts between the different users of ecosystem services. Particularly, in fisheries, there are many conflicts over the use of space:

1. Conflicts between different fishing gears: There are restrictions on some areas to certain fishing gears, for instance depth limits for trawlers or purse seiners.
2. Marine Protected Areas: There are many different types of protection, the most severe of which restrict all fishing, some others restrict specific fishing gears or limit the number of fishing boats, and others offer only seasonal protection.
3. Vulnerable species: Some species may have high levels of protection as they are considered sensitive and vulnerable. They can be scarce or confined to a particular habitat, threatened or their populations are at low levels.
4. Essential Fish Habitats: Some particular areas are protected due to the presence of juvenile fish, which can result in high levels of fishing discards and unwanted catch.

A Marine Spatial Planning approach can provide further insights in fishery management, considering the spatial information on where natural populations and fishing occur. It is well-known that spatial patterns, local movements, migration patterns, and more general geographical scenarios are thought to play an important role in the dynamics of fisheries resources (Warren 1998; Fogarty and Botsford 2007).

However, to get reasonable estimations and predictions of abundance, including a description of variability, models must describe the relevant species interactions, effects of environmental conditions and fishing effort by gear at appropriate spatial and temporal scales (Sims et al. 2008; Elith and Leathwick 2009; Vilela and Bellido 2015). There are obvious relationships between fishing effort, habitat properties, catchability and fishing mortality, and all these features have to be considered in order to enhance fisheries management in the framework of a MSP approach.

A key point to reduce discards and achieve more environmentally responsible fishing is to minimize fishing operations in inappropriate areas. It is quite obvious that any management of unwanted catches should consider measures to avoid areas or periods with high abundances of bycatch and discards. Bellido et al. (2011) numbered the three main pillars to reduce discards and unwanted catch:

1. Avoid fishing in areas of higher discards, related to improving fishing strategies by an adequate selection of the fishing grounds.
2. Better selectivity of fishing gears, allowing avoidance and escape of unwanted catch to increase survivability.
3. Valorization of the unwanted catch, with a progressive positive input of fish processing technology and adding value. This is complimented by research to provide new fish products when needed (burgers, nuggets, etc.) as well to use fish material for other uses (pharmaceutical, cosmetic, aquaculture feed producers, biomedical, etc.).

MSP is totally related to the first pillar. With that aim, sensitive areas for particular species or early life stages should be identified, as well as the derivation of areas of special protection for mobile gears and the classification of more suitable fishing areas for “mobile” and “non-mobile” fishing gears according to habitat and fish community characteristics. This research may allow a better understanding of spatial and temporal distributions and abundances of discards, together with an online handling and updating of information, to assess the health of the ecosystem on a spatial basis.

Although scientific advice is indeed essential for an appropriate MSP implementation, MSP scientists should show awareness, support and openness to advice. They should support stakeholders and policymakers by providing knowledge on every specific spatial scale and provide tools to transfer research to advisory products for better spatial planning. For example, a quite accessible and useful outcome is to provide maps and indicators that help managers and users with better decision-making when considering a space-time scenario.

MSP scientific advice is mainly based on the application of mapping tools together with a set of different statistical models and other computational techniques, all on a spatio-temporal basis (Fig. 12.1). Unfortunately, these tools have often been ignored in fisheries management, mostly due to both a lack of appropriated knowledge of fisheries researchers to apply these tools and a lack of involvement of spatial researchers to provide technical advice for the quantitative and qualitative spatio-temporal analysis.

Here we provide two examples of how to apply these techniques to provide scientific advice for MSP, particularly related to Landing Obligation issues. The first one is related to the establishment of an online GIS platform to inform fishers of areas where they can maximize yield by minimizing discards. The second one is a simulation of spatial fishing closures to test different MSP scenarios for a purse seine fishery in South East Spain. The findings and applications of these two case studies can help fishery managers make decisions to mitigate discards in European waters.

This work was developed in the framework of the iSEAS LIFE+ project, “Knowledge-Based Innovative Solutions to Enhance Adding-Value Mechanisms

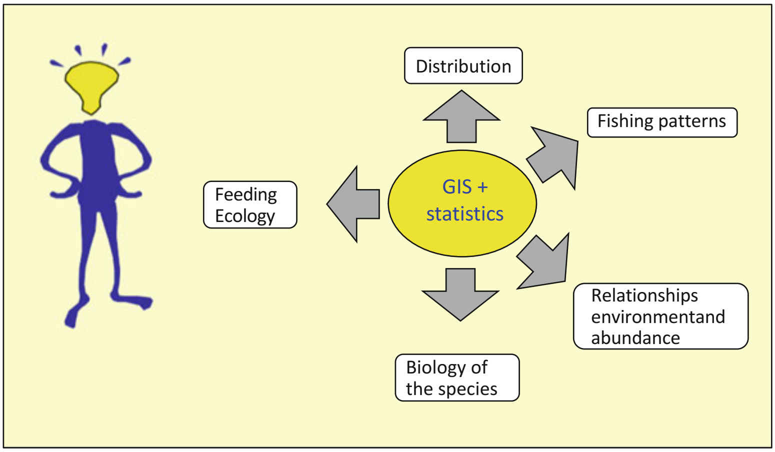

Fig. 12.1 Possibilities of spatial techniques in MSP, how to integrate different statistical models and other computational techniques, all on a spatio-temporal basis

towards Healthy and Sustainable EU Fisheries". iSEAS WP3 was totally devoted to applying spatial models to reduce discards and increase efficiency and these case studies are an example of that approach.

12.2.1 An Online GIS Platform to Mitigate Discards

Over the past decades, a branch of IT (Information Technologies) has gradually evolved, specifically dedicated to mapping and spatial analysis. This technology is usually referred to as Geographical Information Systems (GIS), though it has also been called geo-data systems, spatial information systems, digital mapping systems and land information systems. A GIS comprises a collection of integrated computer hardware and software which together is used for inputting, storing, manipulating, analyzing and presenting a variety of geographical data. Applications of GIS to marine fishery resources, or indeed to any marine applications, have been very limited, being mostly confined to peripheral areas such as coastal zone management, pollution modeling and controls, mariculture and shoreline mapping (Meaden 2000).

One of the objectives of our work was to develop a fully-operative GIS tool that integrates predictive models of suitable fishing areas for Northeast Atlantic fisheries (Fig. 12.2). This is a real time modeling technique, which could help fishers avoid areas or periods with high probability of unwanted bycatch/discards (Vilela and Bellido 2015). Such a model aims to minimize discards/bycatch throughout the study area through flexible real-time modeling of recent catches and discards, which produces maps as final results, i.e., outputs that are easy to interpret by fishers (see Fig. 12.3). The final aim is to provide additional info to skippers to carry out their fishing strategies taking into account which species are in the area and in which

Fig. 12.2 Schematic of the automatic procedure for data acquisition and main page of the GIS platform. (http://iseas.cesga.es/)

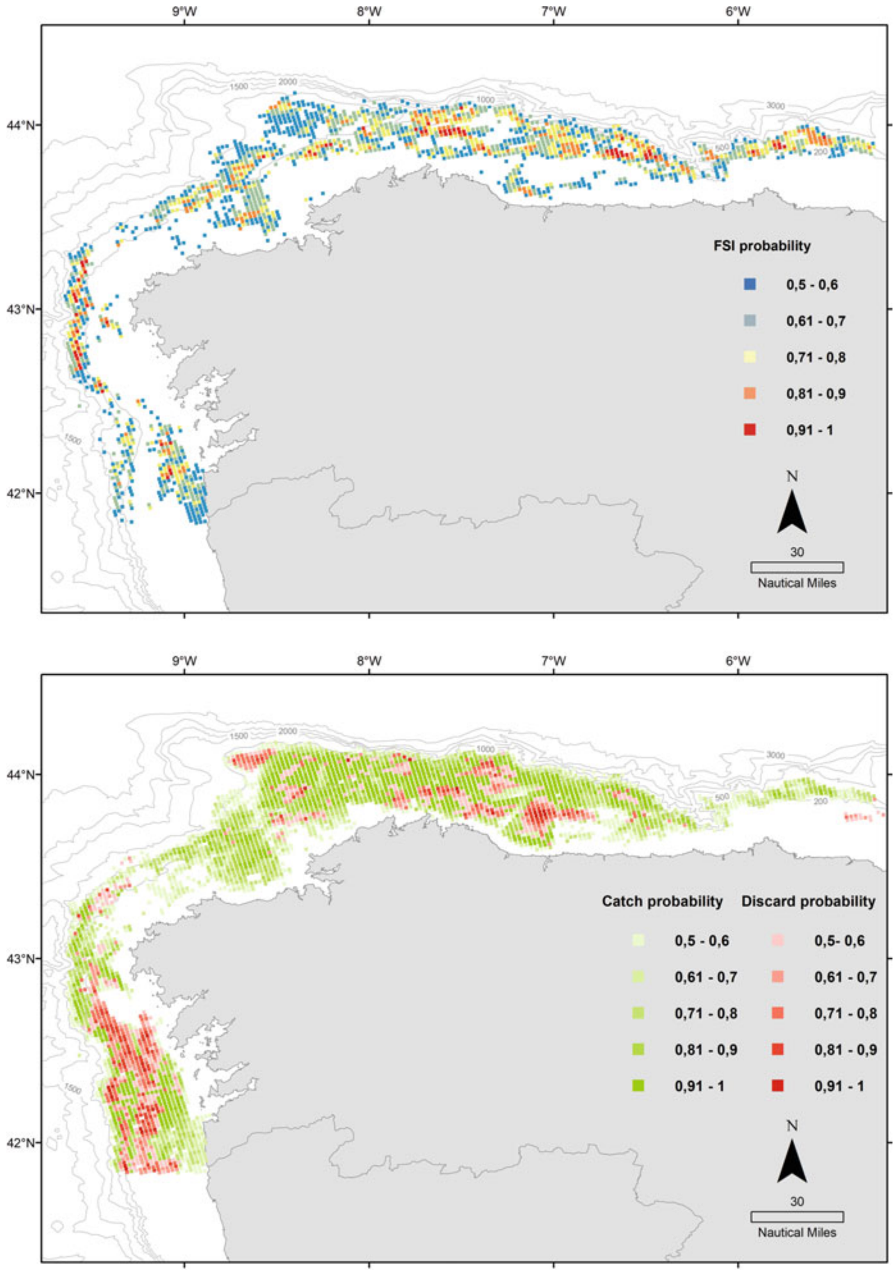

Fig. 12.3 Model results for *Merluccius merluccius* in area ICES VIII-west and area ICES IXa: FSI annual probability (upper image), with the best fishing areas in green; catch probability (bottom left), with higher probabilities of positive catch (i.e. distribution area of the species) in dark green; discard probability (bottom right), with higher probabilities of discard rates of more than 20% in orange

catch composition, and as a consequence, the kind of discards/bycatch to be expected.

Fishery data are provided for the fishing vessels in an automatic way (Fig. 12.2). The participation of fishing vessels is voluntary, but only fishing vessels providing data can benefit from the online results. As a result, fishing vessels will act as online sensors that continuously provide real data from the daily activity of fleets both to the models, as well as to the GIS platform. This fact will make models more accurate and precise (in terms of predicting target species/discards) for fleets working in a given area, while reducing costs because previously this task was done by specialized observers on oceanographic and research vessels.

Once the user logs into the GIS platform, the general layer information is displayed in a small, interactive box. The modeling process starts when the user performs a query which generates a temporal fishing data subset extracted from the general SQL database stored in the system. This temporal fishing data subset collects information regarding the latitude, longitude, and species-specific information on the weight caught and weight discarded of each fishing operation performed by the fleet in the selected area and time period. Explanatory variables used for the analysis include bathymetry, slope, distance to the coast, sea bottom characteristics, Sea Surface Temperature and Chlorophyll-a concentration. Other important explanatory variables, such as the season, fleet characteristics, etc., are intrinsic and self-contained in the fishing data used to perform the modelling.

The model estimates the Fishing Suitability Index (FSI) for a given operational unit (métier), time period and marine area. It is defined as the probability of a location to have low discards, i.e. below a defined threshold discard rate, based on its environmental characteristics and previous fishing activity information (Vilela and Bellido 2015). The script, developed in R open statistical software, reads the temporal data subset and transforms catch and discard data for each record into a FSI binary variable according to the maximum admissible discard rate (threshold). The script also reads the environmental variables for each fishing location from a 2×2 km grid loaded in the working space of R and transfers the variables to the temporal subset with the fishing data.

The models are based on the Breiman-Curtis algorithm (Random Forest; RF) and do not have any methodological assumption to be checked prior to the analysis, except the independence among observations, making it a strong method for an unsupervised and automatic model. Although RF is not a suitable tool for hypothesis testing, it is a robust non-parametric statistical method for data analysis that makes no distributional assumptions about the predictor or response variables (Cutler et al. 2007), thus making it an ideal candidate for inclusion in a flexible and fully automated ecological prediction system. It is worth noting that Crisci et al. (2012) concluded his review of different machine learning algorithms over rocky benthic communities by highlighting the properties of RF as, "*one of the most efficient learning algorithms in terms of prediction accuracy*".

Model results are projected for the whole area using the 2×2 km grid, and resulting maps are stored in a vectorial GeoJSON format in a local folder of the server. The maps and a text file with information regarding the performance and information about the fishing data processed (i.e. number of records with catch, number of records with discards, percentage discarded, average FSI, mean catch, and mean discards) are available.

In the last step, the geoportal shows the GeoJSON vectorial image in a web-mapping service and shows the user a measure of the model performance, according to predefined probability values (FSI index):

- Between 0 and 0.5: Red zone, less suitable areas for fishing (high discard proportion).
- Between 0.5 and 0.8: Orange zone, intermediate areas for fishing (medium discard proportion).
- Between 0.8 and 1: Green area, the most suitable areas for fishing (low discard proportion).

Results vary between species, areas and métiers, achieving good results with less than 50 records for target species, while poor predictions are obtained for those bycatch species less influenced by environmental factors. Some examples of the map tool generated for hake (*Merluccius merluccius*) are presented in Fig. 12.3.

These prediction tools help fishers avoid areas or time periods with high probabilities of obtaining unwanted bycatch/discards since they produce maps as final results, i.e., outputs that are easy to interpret by fishers (Vilela and Bellido, 2015). Also they are able to perform both short term and long term predictions, adapt to any species, area and fishing operational unit and they are quick, i.e., results can be visualized by the user in seconds. These prediction models provide a good predictive accuracy and offer an assessment (or goodness of the fit) about the reliability of the prediction visualized to the user.

This GIS platform is accessible to the public from http://iseas.cesga.es/ where some of these maps and results are displayed.

12.2.2 MSP to Reduce Discards in a Small Pelagic Fishery off South East Spain

Along the Spanish Mediterranean coast, the purse seine fishery mainly harvests small pelagic fish (Fig. 12.4). The most common type of fishery operates during the night and mainly targets anchovy (*Engraulis engrasicolus*) and sardine (*Sardina pilchardus*). Purse seine fisheries are characterized by actively searching for fish using echo acoustics. This makes it a reasonably selective fishery with generally lower discard rates than trawlers, gillnetters and longliners, thus attracting fewer studies related to discards.

However, despite relatively low mean discard rates in purse seiners, a huge variability per haul is present ranging from 0% to 100% of the catch being discarded (Borges et al. 2001). This high variability is influenced by the electronic equipment used to identify and target fish schools, failing to correctly determine the species composition or size of a school and can lead to the whole volume of the haul being discarded.

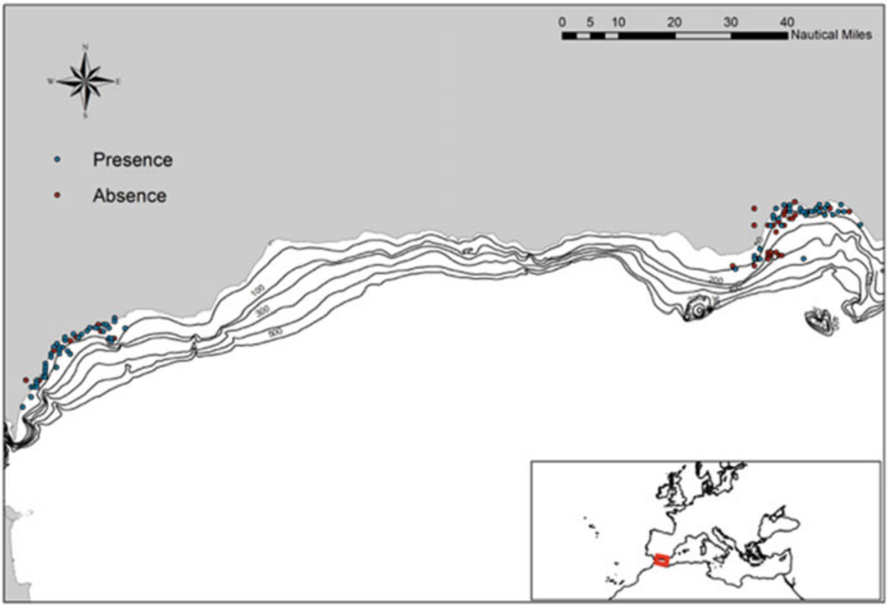

Fig. 12.4 Depiction of fishing locations in the purse seine fishery in South Spanish Mediterranean. Dots represent hauls in the two main fishing grounds, Bay of Málaga (western area) and Bay of Almería (eastern area)

We explored the Spanish Mediterranean purse seine reference fleet with respect to discards to identify potential discard driving patterns. We simulated different fishing closures and explored how they can affect catch compositions and discard patterns. This study is based on data collected by the Spanish Mediterranean on-board observers program, for which the purse seine reference fleet is located in the Northern Alborán Sea (GSA01). The Alborán Sea has 11 ports, although the data set covers the two main sub-areas of the Northern Alborán Sea (Almería and Málaga). The data set comprises 108 fishing trips and a total of 173 fishing operations from 7 different vessels during a 3 years period (2009–2011). It also contains information on the location, time, depth, and moon phase of each haul, as well as characteristics of the vessel such as gross registered tonnage (GRT), length and power (HP).

As usual in fisheries, the abundance of discards in purse seiners is characterized by a relatively high number of zeros. In these cases, data modeling has to take into account both zero and non-zero observations. Models able to do so are known as zero-inflated models. However, most of these models have been developed for discrete data and cannot be implemented for continuous data, such as discard volumes. Data with this characteristic are known as semi-continuous data. In the present analysis we have applied a 2-stage model to simulate the semi-continuous behavior that characterizes discards of the Spanish Mediterranean purse seiners. We first fitted a Bayesian generalized linear mixed model (GLMM, Muñoz et al. 2012) to model the occurrence (presence/absence) of discards according to technical and environmental factors that characterize discard occurrence. Then, conditional to presence, we modeled the abundance of the discards using Bayesian geostatistics. In this case, log-transformed discards were used to down-weight extreme values and ensure a better fit of the models.

Regression models such as generalized linear models (GLM-GLMM) and generalized additive models (GAM) were selected as the main candidate approach to uncover the relationships between the amount of discards, expressed in kilos, and some independent covariates. A stepwise approach, based on the estimation of the Akaike Information Criteria (AIC) and the Deviance Information Criteria (DIC) value for each model, was applied to select the final model. This study did not aim to estimate the differences among vessels, so we introduced vessel as a random noise effect in every model. This way, we expected it to absorb the variability that encompasses different purse seine discarding behaviors for each vessel, which can occur due to various technical, social and/or economic reasons.

In addition to discards, a couple of complementary models were fit. First, a Poisson GLM model was designed to fit the relationship between the number of species caught and bathymetry. Additionally, two linear regression models were fit; one for the retained fraction of the catch and the other for the discarded fraction.

Fisheries management has used a wide range of different fishing closures. Some are used as general regulatory principles, such as minimum depth and proximity to land, and others are usually applied on a more regional scale, such as spatial, temporal, and spatio-temporal closures. Here we present a fast, simulation-based approach to easily quantify the impact of applying any such fishing closures in terms of efficiency, in this case lowering discards. Assuming that the available data is representative of the local purse seine fishery, we first simulated a fishing closure and removed all observed hauls that fell into that fishing closure window. Then, we resampled the resulting hauls with replacement and calculated the mean. We then repeated the process N times and compared the results with the whole population. This process was applied to both Almería Bay (simulating 6 fishing closures) and Málaga Bay (simulating 7 fishing closures).

All sampled hauls summed up to 249 tonnes of retained catch and 25.1 tonnes of discarded fish, of which 15.8 tonnes were non-regulated species under the Landing Obligation. The mean discarding ratio of the fishery is 12.3%, with a bootstrap confidence interval between 9.6% and 15.2%. Discard ratios were higher in Málaga than in Almería for both the whole discarded fraction and the non-regulated fraction (Fig. 12.5). Discarding behavior was very variable; we found differences within Málaga and Almería that showed evidence of heterogeneity of discarding at this regional mesoscale.

Results showed that the most significant variable explaining discards was depth for both areas. The model found a negative relationship between depth and the occurrence probability of discards, i.e., a higher occurrence in shallower waters (< 50 m) and a lower occurrence in deeper waters. Also, the number of species caught and discarded decreased with depth (Fig. 12.6), and retained weight per haul increased with depth, up to approximately 130 m. Discarding behavior was also shown to vary significantly between vessels, suggesting individual skipper's fishing preferences may also influence the catch composition of each haul.

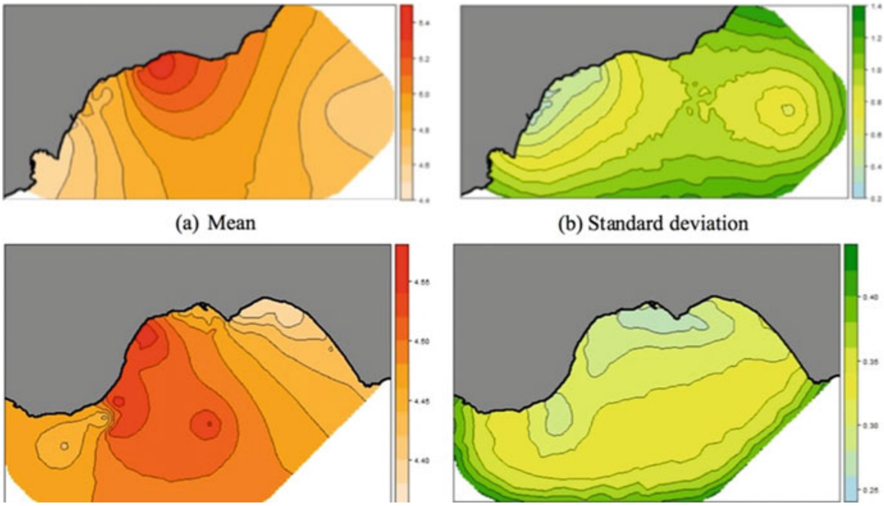

Fig. 12.5 Predicted log-kg of discards in the Bay of Málaga (upper) and Bay of Almería (bottom). Maps show mean (left) and the standard deviation (right) of the predictions

Regarding simulation of fishing closures, both bays show the same pattern and we found no significant differences among fishing closures both in Málaga and Almería (Fig. 12.7). This can be explained by the stable pattern of fish occurrence in both bays as well as a similar discard behavior along the bays. The removal of hauls in every virtual fishing closure is rapidly compensated with hauls in the non-protected areas, generating approximately the same discard level. Hence, the most important spatial effect is therefore bathymetry, and that should be the criteria for any MSP approach to this fishery. As a summary for this fishery, we recommend better enforcement of the purse seine fishery ban in shallow waters (< 35 m), which is currently ignored by many skippers, as the best strategy to minimize purse seine discards in this area.

12.3 Challenges and Opportunities of MSP

Fisheries management is a challenging discipline where biological, social and economic factors converge to form a complex web of interactions, all occurring in a defined geographical scenario. Hence, Marine Spatial Planning presents an intuitive, complementary and natural approach to enrich fisheries management towards more sensible and effective strategies.

MSP requires a profound knowledge of fishing grounds, and not just focused on target species. The monitoring of fishing operations faces formidable technical challenges due to the combination of a target that varies in space and time and a mobile exploitation activity. In many exploited fisheries, the large number of species involved, the high number of fishing gears employed, and the widely dispersed

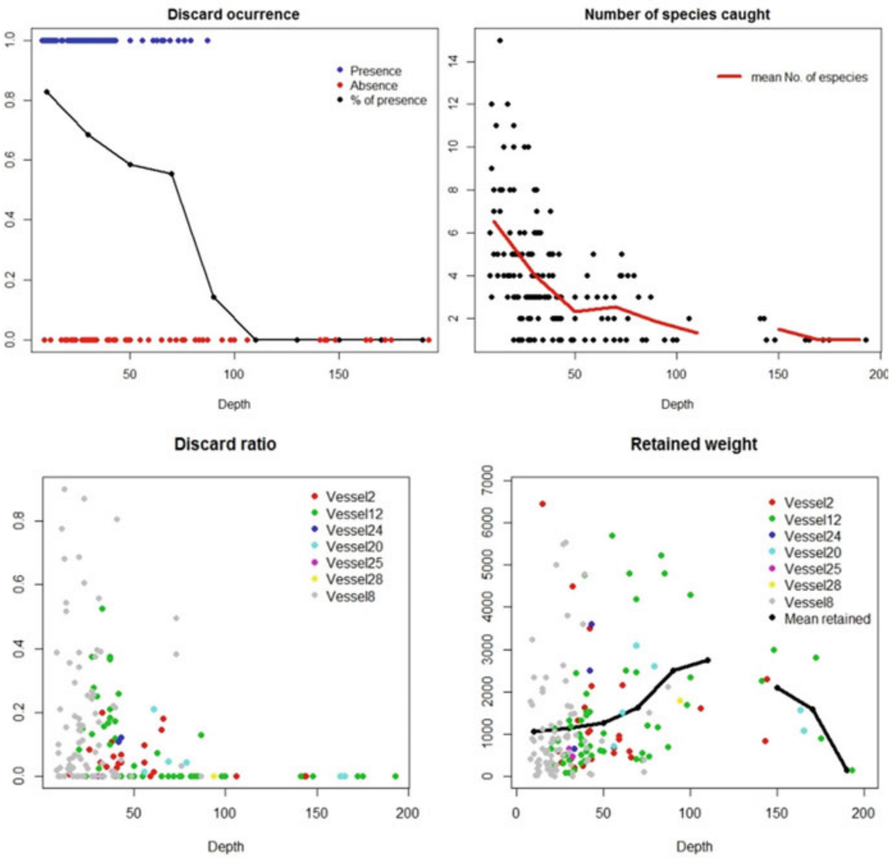

Fig. 12.6 Upper left: presence/absence of discards against depth; in black, the percentage of hauls that present discards every 20 m depth stratum. Upper right: heterogeneity of hauls versus depth; in red, the mean number of species per haul every 20 m depth stratum. Bottom left: discard ratios of each haul versus depth at the location of the haul, differentiated by vessel. Bottom right: mean total retained weight per haul versus depth at the location of the haul, differentiated by vessel. Also shown is the mean retained weight per 20 m depth stratum (i.e. 0–20 m, 21–40 m...), missing data for stratum 120–140 m

landing ports make monitoring, enforcement and compliance measures extremely difficult (Williams and Corral 1999). As a consequence, huge costs and workload are entailed on already overburdened institutions, not always with the required or expected results. In other words, monitoring actions are not as exhaustive as required, in the sense that they are not implemented in every vessel all the time.

Technology could help to implement MSP. To monitor, control, and document full catch and discard information, several alternative data sources are available: inspectors, Electronic Monitoring with video, monitoring via GPS and sensors, naval and air patrols, reference fleets, landing controls, satellite tracking with VMSs (Vessel Monitoring Systems), and the fishers' self-reporting (including

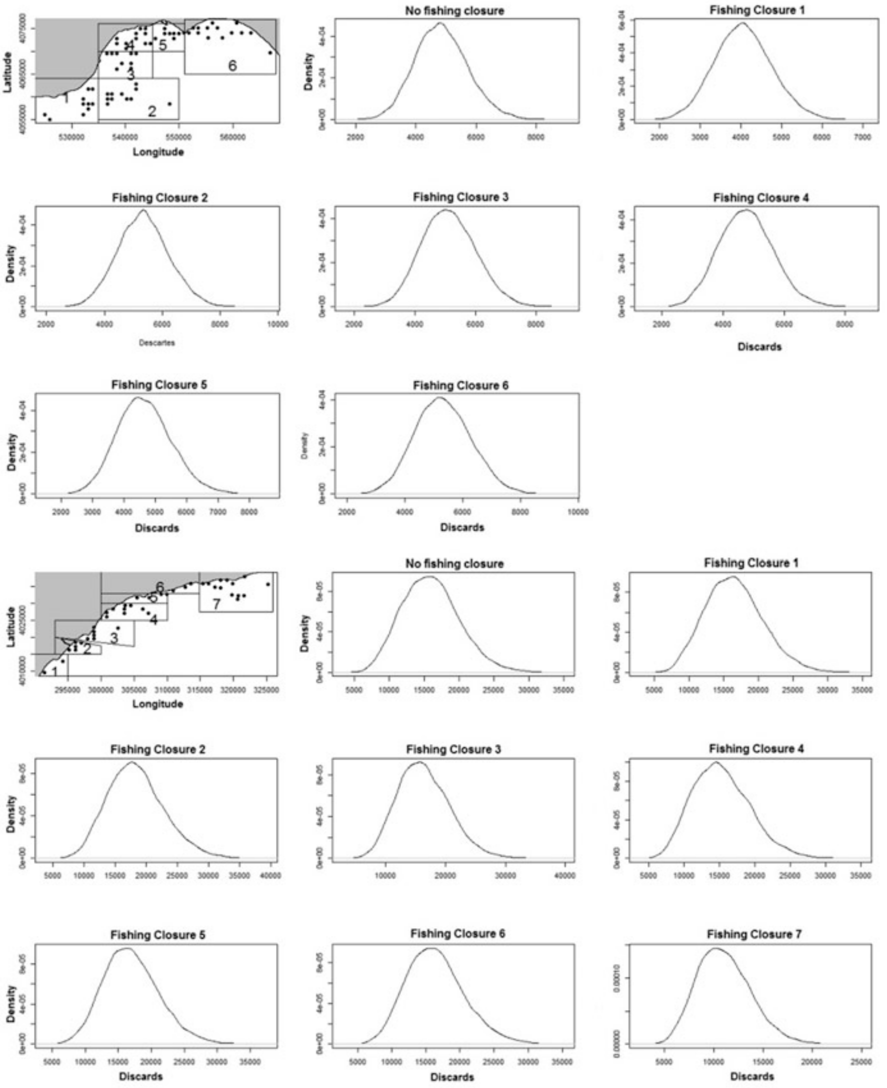

Fig. 12.7 Estimated discards (kg) for every virtual fishing closure for Bay of Almería (top panels) and Bay of Málaga (bottom panels)

logbooks, landing declarations, and sales notes). It must be noted that novel technologies for fisheries monitoring do not replace traditional control and surveillance methods, such as inspections onboard vessels or on shore. However, used correctly, the new technologies should help to better target actions and therefore cut costs and increase effectiveness (James et al., this volume). By crosschecking data collected using the different systems, fisheries authorities can apply risk based control strategies and detect illegal activities that could otherwise go unnoticed.

When fully implemented the main benefits of this system will include:

1. *Quasi* real-time monitoring (depending on when catch information is transmitted) of catches by all fishing vessels operating in EU waters and of fish quotas.
2. Protection of valuable commercial fish stocks by appropriate stock assessments based on real catch data.
3. Efficient and effective data interchange between agencies engaged in fisheries monitoring and control across the European Union.
4. Reduced requirements for manual entry of logbook data into central databases.

The defined area, time scale, and review period may not be the same for different legal obligations, policy and management goals, and operational objectives. The validity of the goals and objectives should be assessed by SMART criteria (Specific, Measurable, Achievable, Realistic and Time-bound).

Policy approaches can be top-down (imposed by government), bottom-up (meeting popular demands from end users), or a combination of the two. The balance between these policy approaches will give an indication of how likely end-users will be to follow enforcement laws.

A real challenge is to avoid duplication of effort by different public agencies and levels of government in MSP activities. It is necessary to provide a rational basis for setting priorities, as well as to direct resources to where and when they are needed most. If resources are limited, then a prioritization exercise could be undertaken to consider the relative importance of ecological, social, economic, and other operational objectives.

A quite useful product to design and start a MSP approach is the UNESCO Step-by-Step guide (Ehler et al. 2009). This guide is directed towards professional marine managers, and it provides a complete view of MSP and describes a logical sequence of steps that are required for successful MSP implementation.

Additional initiatives aimed at progressing towards MSP are underway. MESMA (www.mesma.org) was an EU-FP7 project on monitoring and evaluation of Spatially Managed Marine Areas. One of the main outcomes of this project was the elaboration of a roadmap to implement MSP. Since MESMA has finished, the MSP movement has been gathering throughout the European MSP Platform (http://msp-platform.eu), which provides information and tools for MSP in different European sea basins.

12.4 Summary and Policy Recommendations

The best discard mitigation measure occurs at sea; not catching unwanted bycatch. The key aspect should be better fishing practices to avoid unwanted catch.

A better marine spatial planning approach is needed for fishery management. These types of measures can be more flexible and dynamic in response to spatial and seasonal restrictions related to fishing. Depending on the population, the measures can differ, for instance we suggest spatio-temporal fishing restrictions for vulnerable sizes and/or areas. Regarding spawners, they could be protected through planning for temporal (seasonal) closures. These temporal closures should be applied to all métiers at the same time.

In the cases studied here, depth fishing restrictions appear to be one of the best management measures, and they are totally based in MSP. There are several prohibitions that are essential to our knowledge and should be maintained and, in some cases, better enforced. These are the prohibition on purse seine fishing shallower than 35 m or over sensitive habitats, the prohibition on trawl fishing shallower than 50 m or over sensitive habitats, and the prohibition on all fishing beyond 1000 m.

The Landing Obligation should be accompanied by other measures for its successful implementation. Some of these measures are improvements in fishing effort controls, effective enforcement, and finally an agreement from the fishing sectors to comply with rules and regulations.

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