



# Discarding in Mediterranean trawl fisheries—a review of potential measures and stakeholder insights

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## Abstract

The multi-species/multi-gear nature of the Mediterranean fisheries, the high number and dispersion of landing points, and the varying motivations for discarding make regulation enforcement in the basin challenging. In this study, reasons for explaining discarding are initially explored and then the main focus is on identifying potential incentive mechanisms and other measures that could reduce unwanted catches in Mediterranean trawl fisheries, in the face of the recent landing obligation. Both literature review and stakeholder engagement are employed, while special emphasis is put on the role of socio-economic tools to influence fishers' behavior. Results show that although discarding is mainly driven by market demand, a number of factors have a synergistic effect which is sometimes difficult to disentangle and capture. Regarding measures, evidence from involved stakeholders (marine scientists and fishers) shows that economic incentives but also “social measures” such as more involvement of the industry and raising awareness are offering common ground. However, specific concerns have been also expressed on measures applicability. Overall, reducing discards is a complex issue and solutions should involve a combination of management measures designed for specific fleets and regions. However, irrespective of the synthesis of the management options, it is important to create a framework of action that takes into account human behavior as a source of variability. In this context, actions that for example encourage, engage, and enable can incentivize behavioral change in order to achieve specific outcomes.

**Keywords** Discarding · Socio-economics · Measures and incentive mechanisms · Mediterranean Sea

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## Introduction

Discarding has been identified as the dumping overboard of dead or alive, unwanted fish or any type of marine animal (e.g., protected species, seabed organisms) caught as bycatch during fishing operations. The mitigation of discards is a major concern to conservation bodies and the wider public (Catchpole and Gray 2010), as discards are linked for example to mortality of juvenile fish, benthic species, and potential loss of biodiversity. In addition, a set of economic issues arise such as the costs at the level of the fisher, the fisheries authorities (e.g., monitoring and control, observer programs), and society in general (e.g., costs associated not only with foregone landings of commercial species but also with the ecosystem impact of discards) (Kelleher 2005). In the context of the European Union (EU), the need for more action regarding discards is reflected on the recent discards ban (obligation to land all catches) for certain species which is included in the reform of the EU Common Fisheries Policy (CFP) (European Commission 2013).

Focusing on the Mediterranean, the main fisheries are bottom otter trawlers, pelagic trawlers, and purse seines, drifting longlines and small-scale fisheries, while the trawl fishery is the second largest in landings after small pelagic fisheries (Bellido et al. 2014). The General Fisheries Council for the Mediterranean (GFCM) of the Food and Agriculture Organization (FAO) and the Scientific, Technical and Economic Committee for Fisheries (STECF) of the EU assess the status of fish stock in the Mediterranean and Black Sea and provide scientific advice based on observed levels of exploitation rate in accordance with the EU's CFP (Vasilakopoulos et al. 2014). In general, the multi-species/multi-gear nature of the Mediterranean fisheries results in fisheries which are highly diversified both geographically and among the different fishing gears in terms of catches, target species, sorting practices, and discard composition (STEF/SGRN 2006). In addition, the high number and dispersion of landing points makes accurate monitoring, control, and regulation enforcement difficult (Kelleher 2005). IUCN report highlights that marine Regional Fisheries Management Organizations have achieved mixed progress in governing bycatch and discards, with the General Fisheries Commission for the Mediterranean achieving one of the lowest scores in a number of criteria (Gilman et al. 2012). Tsagarakis et al. (2014) estimate a rough Mediterranean-wide estimate of discards of around 230,000 t or 18.6% of the catch, while bottom trawl is the fishing gear that exploits a great diversity of species and produces the highest portions of discards. However, discards ratios for trawls are generally lower in the eastern and southern basin (Tsagarakis et al. 2014). Following Bellido et al. (2014) of the 300-species caught in the Mediterranean, only around 10% are consistently marketed and 30% are occasionally retained (depending on the sizes and market demand) whereas up to 60% are always discarded.

The Council Regulations (CE No 1967/2006) (European Commission 2006) have established a combination of technical

regulation, including gear modifications and gear restrictions, fishing effort limitations, spatial area closures, and management regulations such as Minimum Conservation Reference Size (MCRS) for several species in the Mediterranean. In the basin, discards mitigation actions mainly comprise technical measures, which are related to improvement of selectivity, and/or spatial measures such as avoidance of potential hot spots of discards, involving spatio-temporal closures for protecting species at certain stages of their life history (e.g., protection of juvenile nursery areas or adult spawning grounds) (Tsagarakis et al. 2014). Regarding the recent obligation to land discards, according to Article 15 of the CFP, all catches of species managed by quotas/catch limits and minimum landing sizes should be landed. In the Mediterranean where there are no quotas, except for bluefin tuna, this regulation affects all regulated species with minimum landing size listed in Annex III of Regulation EC 1967/2006 (European Commission 2006), except when used as live bait (Bellido et al. 2014). The regulation is introduced gradually according to a schedule based in different areas, fisheries, and species. In the Mediterranean, demersal fisheries catches subject to MCRS must be landed progressively starting from January 1, 2017.

Overall, important elements for the management of the discards issue seem to be the existence of explicit performance standards, in combination with adequate observer coverage and complete data collection (Gilman et al. 2012), as well as an understanding of the factors driving discarding (Rochet and Trenkel 2005; Feekings et al. 2012). Regarding the latter, it is important that the adopted approaches should be designed by taking into account not only economic factors but also the emotional roots of stakeholders' decisions and the social capital of the area of implementation, including factors such as shared norms and values, interpersonal relationships, and trust. However, it becomes challenging selecting the appropriate measure(s). This is also due to the difficulties in understanding the trade-offs between the short and long-term benefits and costs (socio-economic and environmental) of different approaches that need to be counterbalanced before decision-making (Hall and Mainprize 2005; Suuronen and Sarda 2007).

The aim of our study is to initially review the literature for drivers of discarding before we focus on mitigation measures. Regarding the latter, emphasis is put on incentives and other mechanisms that could contribute to behavior change and reduction of discards in the Mediterranean trawl fisheries in the face of the recent landing obligation. Furthermore, we aim to gauge stakeholders' view on tools and incentives previously identified. This will enable to highlight preferred measures and explore perceived challenges that need to be overcome in order to enhance the effectiveness of a management framework aiming to reduce discards in the basin.

The present work is structured as follows. In the first section, we present the employed methods. In the following three sections, we explore through literature review drivers and

factors of discarding as well as mitigation tools. The latter include technical and spatio-temporal measures as well as potential incentives and other mechanisms. In the fourth section, we present the evaluation of measures (previously identified) performed by involved stakeholders, along with an analysis of their qualitative answers in relation also to findings from literature. Finally, a discussion follows on drivers, measures and their link and main conclusions are drawn.

## Methods

For this study, employed methods involved two main steps, literature review and stakeholder engagement. First, literature review was conducted regarding (i) drivers influencing discarding behavior and (ii) potential measures and incentives. Literature related to both empirical applications and conceptual models was considered and peer-reviewed papers and gray literature, including technical reports, were reviewed. Special consideration to trawl fisheries discards in the Mediterranean Sea was given. Then, engagement with specific stakeholders (marine scientists and fishers) was sought. In particular, 14 marine scientists, mainly fisheries biologists with a solid knowledge and expertise both on fisheries ecology and fisheries management, about five from each country, Greece, Italy, and Spain, were consulted. Scientists were involved in the DG MARE project “Catch and discard composition including solutions for limitation and possible elimination of unwanted bycatches in trawl net fisheries in the Mediterranean (DISCATCH). Respondents also included representatives of the fishing sector (i.e., trawling associations mainly deep and self bottom) from the three countries (10 in total) and individual trawlers (7 in total) where access and availability of representatives were not possible. It is noted that overall, no striking differences were revealed across segments of involved fishers. During the survey, participants’ views were gauged on mitigation tools and incentives, previously identified through literature review, based on their experience in their country. In particular, all participants were asked to evaluate the effectiveness of suggested tools in reducing discards, using a close-ended format. Then, they were asked to identify (open-ended format) any other intervention that was not included in the list and comment on potential combinations of interventions that they deemed necessary so that the landing obligation is successfully met in their country. It is noted that we do not expect order bias related to the questions to be an issue due to the familiarity of the respondents with the topic. The survey, that was conducted in summer 2015, was emailed to scientists, while fishers filled out the questionnaire together with one of the researchers working in DISCATCH project.

It is acknowledged that the employed data collection may be linked to some type of interview bias although, interviewers were standardized and given instructions before contacting fishers. In addition, the background of involved

researchers linked mainly to fisheries biology is expected to be reflected in their answers. Regarding the sampling method, stakeholder engagement did not involve a random representative sample aimed for rigorous statistical analysis or group analysis in order to generalize results. Non-probability sampling was employed based on respondents’ availability that aimed to explore the effectiveness of discard related measures in the specific geographical scale as expressed by the involved participants. Therefore, it is acknowledged that it is not possible to draw inference between suggestions on measures and interviewee or study area attributes. To analyze close-ended replies, the values that appear more often were used to summarize results, while open-ended replies were analyzed in a way to show the range of views across respondents. Representative quotes by different individuals for potential measures were presented. Finally, it is noted that views on the issue of a wider range of stakeholders such as civil society and NGOs that are not included here are equally important and should be reflected in future research.

## Drivers for discarding

Bottom trawl discards in the Mediterranean consist of (Vrgoč et al. 2007) the following: (i) commercially unimportant invertebrate species (molluscs, crustaceans, holothurians etc.), (ii) commercially unimportant fish species (e.g., inedible), (iii) commercially important but undersized species (under MCRS), and (iv) commercially important species which fishermen could not sell on the market (e.g., fish is damaged or in poor condition) or have very low market price. Hence, apart from legal provisions (regulatory discarding), a considerable part of discarding is explained by the practice of “high grading” or economic discarding.

Overall, at the level of the fisher, the act of discarding involves a short-term economic (profit maximizing) decision that requires weighting a wide range of costs (e.g., cost of sorting and crew share, cost of freezing/catch preservation) and benefit factors (e.g., price of fish) (Anderson 1994; Nautilus Consultants 2001; Kelleher 2005), irrespective of the management system (Pascoe 1997). Regarding market influence, prices are dynamic and, in some cases, even a portion of the valuable catch is discarded to maintain price stability if supply exceeds demand (Mallol 2005). Furthermore, consumers’ preferences that affect market prices and may be related to size can influence the decision to retain or discard commercial fish species (Damalas and Vassilopoulou 2013). Vassilopoulou et al. (2012) also note the existence or absence of a market as a very important driving factor for discards. There are cases that a market exists for small fish and other invertebrates, including those below the MCRS, which are purchased by local fish mongers and restaurants (Kelleher 2005; Katsanevakis et al. 2011; Damalas and Vassilopoulou 2013; Tsagarakis et al. 2017) or

for smaller unmarketable fish that may be used either for own consumption or bait (Kelleher 2005). In addition, nutritional habits of the community and familiarization of customers with species play an important role. For example, the species *Lepidopus caudatus* (silver scabbardfish) has only recently been introduced to some fish markets in Croatia, and the majority of individuals in many areas are still being discarded (Vrgoč et al. 2005; Krstulović Šifner et al. 2009). An interesting finding in Tsagarakis et al. (2014) is that community economic welfare in the Mediterranean bottom trawl fisheries affects resource use of the fisheries catch and wealthier communities produce greater amounts of discards, which seems to be due to regional market demands and palatability habits (community and social influence). Overall, it seems that market demand rather than fish size (legal reason) determines what is discarded in Mediterranean fisheries (Tzanatos et al. 2007).

Furthermore, an important anthropogenic factor which can function as driver for discarding is that of “community” which is the social sphere which influences the fishing practice and mainly the domain of values and norms (Eliassen and Christensen 2012; van Putten et al. 2012; Eliassen et al. 2014). Eliassen et al. (2014) highlight factors which potentially influence discards and selective behaviors related to “community”: general view of discard, institutional knowledge regarding volumes and consequences, social norm enforcement, fishers’ perceived role and interpretation of the management system, and dialogs with the management, individual, and collective initiatives to learn. For example, discarding may not be perceived as an important problem in Mediterranean waters, and in certain cases, fishers even consider it having positive externalities for example, providing food to sea birds (Eliassen et al. 2012, 2014) or representing, in general, an important ecological input (Zhou 2008; Heath et al. 2014). Furthermore, considering community behavioral characteristics, some people comply with regulation without notice and others not due also to moral obligation and social influence (Sutinen and Kuperan 1999). In addition, van Putten et al. (2012) report that individual socio-demographic and psychological characteristics (e.g., family history, attitude towards risk, variability in information levels, reluctance to change) play a significant role in explaining observed fishing behavior. We note that these social drivers may be more prevalent in island communities and small-scale fisheries rather than among industrial fisheries; however, this hypothesis should be further explored.

Apart from market and community, other factors, which may function as drivers for discarding following Eliassen and Christensen (2012) classification, are natural and structural conditions and state (and regulations). Species composition, abundance, and size structure of the catch affect the level of discard. In addition, discarding is affected by technical measures (especially those referring to gear selectivity), fish size legal constraints, control, and enforcement issues and spatio-temporal closures (related to nursery grounds of specific species). Although the

natural conditions are considered very dynamic, these are external to the individual fisher as well as state and market, even though in the medium and long term, they can influence the natural conditions (Eliassen et al. 2014). Tsagarakis et al. (2014) offer an insight into natural conditions and state at the Mediterranean scale and therefore we do not comment any further on these as more emphasis is put on the socio-economic drivers of discarding.

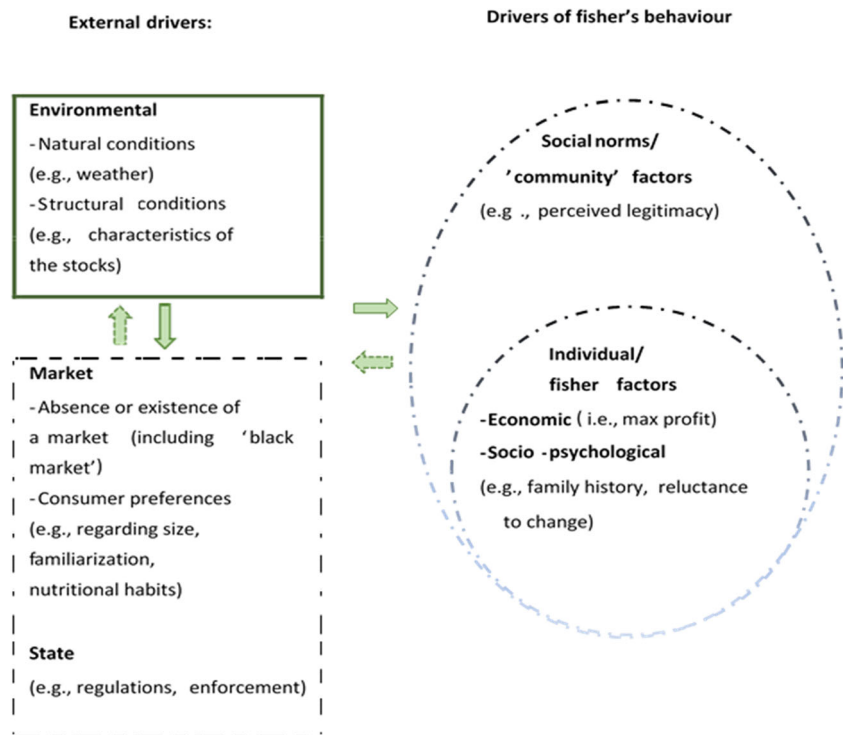
Figure 1 summarizes the above information regarding drivers of discarding. In this context, external drivers (environmental, market, and state) influence fishers’ (individual) behavior, which is a function of fisher’s individual objectives and characteristics. At the same time, fisher is a member of a community that holds specific perceptions and beliefs and operates following specific social norms. These drivers and factors interact mutually, thereby shaping discarding behavior.

Regarding empirical applications, following van Putten et al. (2012) review, though not Mediterranean specific, drivers included in empirical behavioral models regarding discarding were categorized as economic (i.e., revenue, cost, fish abundance, work conditions), individual (i.e., vessel characteristics), and regulation related. Overall, empirical applications on discarding in Europe are scarce (Machias et al. 2001; Borges et al. 2006; Macher and Boncoeur 2010; Poos et al. 2010), especially in Southern Europe (Machias et al. 2001; Macher and Boncoeur 2010; Pennino et al. 2014). Importantly, it is observed that the inclusion of social and social-psychological factors in fishing fleet dynamic models is still very limited although their role in explaining observed fishing behavior is considered significant (van Putten et al. 2012).

## Management measures to reduce bycatch and discards in the Mediterranean

Increasing the selectivity of fishing gear can be a good way of reducing discards in some areas. Several studies in the Mediterranean have been carried out in order to explore fishing gear selectivity in trawl fisheries, and in particular to analyze the effect of increasing the codend mesh size (e.g., Ragonese and Bianchini 2006; Deval et al. 2007; Sala et al. 2015) and to assess the effect of changing the mesh geometry in the codend (e.g., Ordines et al. 2006; Baro and Muñoz de los Reyes 2007). Few studies have also explored the efficiency of sorting grid systems (e.g., Sardà et al. 2005, 2006; Bahamon et al. 2007) while there are devices used to mitigate catches of certain species in the Mediterranean such as the inclusion of turtle excluder devices (Sala et al. 2011; Lucchetti et al. 2016). Finally, fishers themselves may alter the technical characteristics of their gears to avoid unwanted catches. For example, in some Croatian fishing zones, characterized by large quantities of unwanted catches (especially holothurians species), fishers tended to modify their gear in

**Fig. 1** Drivers of discarding. Adapted from Pascoe (1997), Eliassen and Christensen (2012), van Putten et al. (2012), and Eliassen et al. (2014)



order to have “cleaner” catches (Vrgoč et al. 2007). Nevertheless, the effectiveness of technical measures to reduce bycatch of undersized commercial and of non-commercial species in the basin varies, as measures may be gear- and fishery-specific (Broadhurst et al. 2007).

Another category of avoidance measure is the spatio-temporal effort allocation. In this category, also fall marine protected areas and especially those that among the objectives of their establishment have been the reduction of bycatches, mainly concerning vulnerable and charismatic species (Abdulla et al. 2008). In the Mediterranean, both permanent and temporary spatial management measures exist (UNEP 2003). For example, trawl fishing is prohibited on sensitive habitats (coralligenous, *Posidonia oceanica meadows*, maerl beds) and in areas closer than 1.5 nm from the coast and shallower than 50 m depth (European Commission 2006), as these are considered valuable ecosystems and possible nursery grounds of coastal species. Even though the decision to prohibit trawl fishing over these sensitive habitats does not aim at the mitigation of discards, this may contribute to discards mitigation due to the fact that nursery areas are closely linked to such habitat types (Giannoulaki et al. 2013; Colloca et al. 2015).

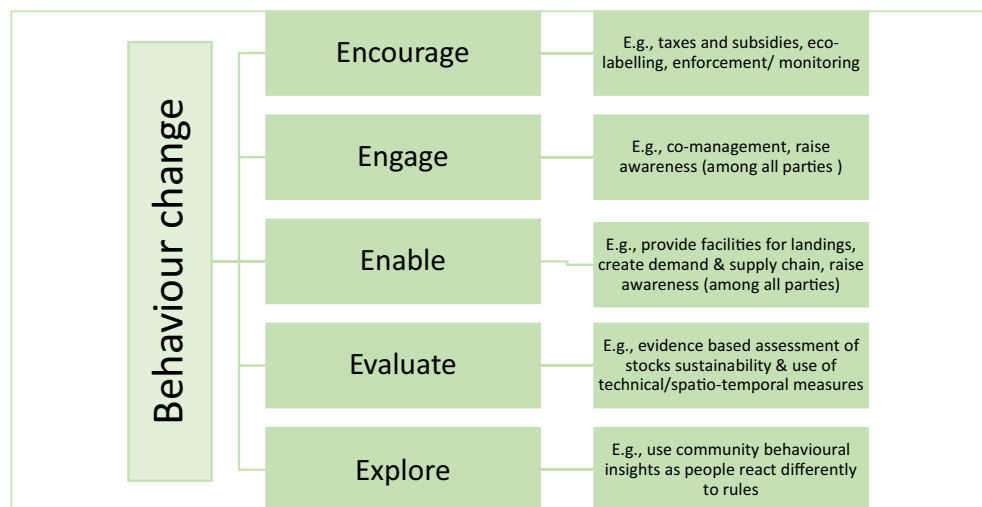
## Incentives and other mechanisms for behavior change

As the availability of the above technologies, measures, and introduction of the landing obligation does not necessarily

mean immediate adoption and compliance by fleets, creation of incentives and use of other means to engage and enable fleet participation might be the key. Overall, knowing how incentives may change behavior is necessary to support both existing mechanisms to reduce discard and to develop new ones (Eliassen et al. 2014). Towards this direction, behavioral economics have a role to play in trying to get to the emotional roots of our decisions (as consumers, fishers) so as to examine the reasons needed to be given in order to change behavior. To achieve that, different forms and combinations of actions may be required (Fig. 2) that encourage, engage, enable but also evaluate suggested measures in order to achieve behavior change (Fishing for the Markets 2011). Based on our literature review, we identify incentives and other mechanisms for behavior change towards discarding such as economic and market-oriented incentives, more involvement of the fishing sector, and society awareness. It is noted that the aim of the literature review here was to explore the range of such mechanisms to be evaluated afterwards by involved stakeholders. Hence, we do not go into a reflection of each of the incentives and mechanisms in this section.

Apart from enforcement/monitoring and charges for failure, a range of economic and financial incentives could be employed to encourage behavioral change. Cost compensation mechanisms, as well as data collection, research, monitoring, and enforcement as other options for passed-through funds (i.e., funds remaining after the fishermen's costs are deducted) have been suggested to adhere to the recent legislation (McIlwain 2015). Economic incentives for discard reduction include taxes

**Fig. 2** Examples of actions related to behavior change. Adapted from Fishing for the Markets (2011)



imposed on discards, subsidies, license, or other fees discounted for use of bycatch reduction device, selective licensing, eco-labelling, buyback programs etc. (Pascoe 1997; Kelleher 2005; Tsagarakis et al. 2014). An example of using incentives to encourage behavior change and mitigate the conflict of small-scale fisheries and Mediterranean monk seals in Greek seas is LIFE project MOFI (2009), in which compensation (e.g., support for damages to gear, support on annual basis) along with management and technical measures was suggested.

Economic incentive mechanisms such as payments for ecosystem services, although not popular in marine resource management, are considered more effective than regulatory mechanisms to reward resource users for improved practices of natural resource or compensate for the benefits forgone from complying with certain use regimes of natural resources (Mohammed 2014). Another market-oriented measure to incentivize and encourage discards' reduction is the eco-certification such as the Marine Stewardship Council (MSC) which aims to create positive market incentives for sustainable fishing by shifting consumers' demand and by enabling eligible fisheries to increase the value of their products. At this point, it is worth mentioning the LIFE Andros Park project<sup>1</sup> (in progress) that aims to create a brand for sustainably caught fish in order mitigate the conflict of small-scale fisheries and Mediterranean monk seals in Andros (Greece). In addition, MINOUW project<sup>2</sup> includes case studies in Mediterranean countries and aims to explore, among others, social and economic instruments to incentivize selective fishing and discourage discarding practices, such as eco-labelling, fisheries certification and promote awareness among industry and consumers. The project also aims to explore the implementation of an EU Discard Trading System. Other measures aiming to

encourage discards reduction that are related to market conditions are motivated from the fact that some species from sustainable stocks are discarded because they are not popular to eat. Regarding nutritional habits, it has been observed that initially, some species that were not consumed have become consumable. For example, the velvet belly lanternshark was almost always discarded across the basin but is now partially commercialized, at least in the Balearic area (A. Carbonell, unpublished data cited in Tsagarakis et al. 2017). In general, an attempt could be made to use marketing tools, value-adding processes, and also raise awareness among consumers about discarding and encourage them to enjoy sustainable and non-traditional seafood choices. An example is the "Fishing for the Markets" project (2011) which was about finding new ways of getting more of the unfamiliar and less-popular fish caught by English trawlers to market. Similarly, the more recent DiscardLess Project<sup>3</sup> has the objective of creating new markets for otherwise discarded fish that have to be landed under the landing obligation.

Co-management and society awareness of discarding and discard related issues across stakeholders (beyond just among the fishers) are two other supporting measures that have been classified as social (Sigurðardóttir et al. 2015). Creating a scheme where responsibility for resource management is shared between state and industry can enable knowledge exchange and hence more suitable discard reduction methods to fit specific fisheries and discard problem, higher acceptability, and higher legitimacy and thereby higher compliance (Sigurðardóttir et al. 2015). In general, even in a simpler form of involving more, the fishing sector in discard mitigation proceedings is more effective than a top-down approach. Regarding fishing behavior adjustments, McIlwain (2015) notes that under the CFP, an alternative option to a detailed technical framework could be to specify high-level output

<sup>1</sup> LIFE Andros Park. <http://www.life-androspark.gr/>. Accessed 9 October 2018

<sup>2</sup> MINOUW—creating a positive change in the sea. <http://minouw-project.eu/>. Accessed 28 July 2017

<sup>3</sup> Discardless—strategies for the gradual elimination of discards in European fisheries. <http://www.discardless.eu/>. Accessed 19 July 2017

goals and allow industry for example to switch gear types, for different types of fish in different areas, and develop innovative gear designs. Similarly, Hall and Mainprize (2005) suggest placing more effort in engaging the fishers in finding appropriate solutions. In return for this flexibility, accountability at the individual fisher/vessel level to demonstrate adherence to the landing option would be a critical prerequisite. Another measure that can enable behavioral change is to raise awareness and change the perception of stakeholders. For example, by informing fishing consumers about species and sizes that would otherwise be discarded contribute to landing a greater proportion of a vessel's catch through the creation of new markets (Sigurðardóttir et al. 2015). Furthermore, aware consumers about sustainable fishing practices engage more for example in supporting eco-labelling and hence contribute to viable fisheries that have taken actions to reduce discards. Environmental NGOs have already an active role towards this direction. Increased awareness across the industry about the negative impacts of discards in stocks and species can be also beneficial especially at local scale where access to information is not always available.

Two other parameters in bringing behavioral change are to evaluate and explore. For example, evaluating the effectiveness of spatio-temporal restrictions and technical measures impacts on building trust between the industry and managers (Vassilopoulou et al. 2014), engaging further the users, and increasing compliance. Finally, exploring local context, social norms and values (van Putten et al. 2012), social capital issues related for example to the level of trust among fishers (e.g., to comply with rules), cooperation, social connections within and across communities, and links between fishers and the regulator are important in ensuring successful fisheries management outcomes (Grafton 2005).

### **Stakeholders' view of management measures to reduce bycatch and discards in the Mediterranean**

Respondents initially provided an evaluation of suggested measures, regarding their effectiveness in reducing discards following the implementation of the landing obligation in the Mediterranean. They were also asked to identify any additional measures and comment on necessary combinations of measures. Table 1 presents main findings from marine scientists and fishers from the three countries scoring for specific measures.

Overall, convergence between the two parties is noted regarding financial and market incentives, more involvement of the fishing sector in discard mitigation proceedings, and actions to raise awareness. Enforcement/monitoring and spatio-temporal fishing restrictions are more favorable interventions across scientists than fishers. Involved fishers seemed to

oppose more frequently to stronger enforcement/monitoring and charges for failure, some arguing that controls and fines are already very strict. However, there were also different views for example: "... widespread habit and the common practice is selling the so-called 'undersized' in a parallel market which lack any form of regulation. Therefore, it is necessary to adopt more forms of control particularly during the landing and in the distribution chain (markets and wholesalers)." Evidence from the Mediterranean shows that weak control and enforcement have resulted in low compliance for adoption of new gear (Papadopoulou et al. 2012; Damalas and Vassilopoulou 2013), as well as phenomena such as a portion of undersized fish to be landed, usually in low quantities, in bottom trawls (e.g., Machias et al. 2004; Edelist et al. 2011; Damalas and Vassilopoulou 2013) but also other gears. Regarding the introduction of the landing obligation, de Vos et al. (2016) study provides evidence from Greek demersal fishers along with Dutch, French, and Spanish. In this study, Greek fishers regard that the implementation of the measure will be difficult in the country due to the fact that undersized fish is still sold in restaurants and fish markets all around Greece during summer (other evidence of parallel market in Katsanevakis et al. 2011; Damalas and Vassilopoulou 2013), because enforcement is low (and unlikely to improve under the current financial situation) and there is no guarantee that other fishers will also comply. Hence, one possible consequence of the new regulation may be the increase in illegal marketing of fish below the minimum size. Landing, storage, and transportation of juveniles will be legal and this can simplify the black-market commercialization (Bellido et al. 2016). Furthermore, enforcement is also particularly challenging due to the high number and dispersion of landing points (Kelleher 2005). Machias et al. (2004) report that Greek authorities have huge difficulties in monitoring the many fishing vessels in remote fishing grounds.

As far as non-convergence to spatio-temporal restrictions is concerned, from fishers' side, one of the reasons may be the lack of evidence about measures effectiveness. Regarding this type of measures, Vassilopoulou et al. (2012) provide insight into Greek trawl fishers' perceptions and reveal that fishers' impression is that certain areas were declared as no take zones without prior scientific evidence, while no monitoring and evaluation of their effectiveness have taken place ever since (similarly as in Papadopoulou et al. 2012). Hence, fishers suggested that measures should be taken on the grounds of solid research, demonstrating the need to build trust between scientists and stakeholders (Vassilopoulou et al. 2014). However, for this type of measures, a level of trust is also expected among fishers. Following McIlwain (2015), spatio-temporal measures can also include real-time short-lived spatial closures (voluntary closures); however, their successful implementation depends on a certain level of trust and/or a third-party data collection.

**Table 1** Summary of key results and comments regarding the effectiveness of selected measures

Stakeholder Measure(s)	Marine scientists	Fishers	Comments
Subsidize more selective gears and provide for free materials to fix/replace damaged gear	High	High	<b>M</b> : positive for subsidizing gear and use of “indirect subsidies” ( <b>Q</b> ). <b>F</b> : although positive, doubts about selectivity were expressed due to multispecies fisheries ( <b>Q/L</b> )
Cost compensation mechanisms for additional land fish landed under the landing obligation	Medium	High	<b>M/F</b> : although both considered the measure effective, fishers showed stronger preference than scientists. They would expect to be compensated by the market or state. Scientists favoured more “indirect subsidies” and reported clearly more answers of medium effect. ( <b>Q/L</b> )
Commercialize unwanted fish(*) for human consumption and/or other use (e.g., fishmeal, bait)	High	High	<b>M/F</b> : positive effect in principle (answers varied mainly from Medium to High) subject to conditions. For example, fishers expressed concerns including lack of infrastructure, benefits not to be direct to the industry, increased competition for fish and pressure on stocks if landings were to be provided to other industries (e.g., aquaculture). Some scientists expressed doubts about the effectiveness of the measure regarding deep bottom trawling. ( <b>Q</b> ). Other concerns include the cost to change social attitude and taste, increase of imports if supply chain is not primed ( <b>L</b> )
Spatio-temporal restrictions for vulnerable sizes and/or areas	High	Low	<b>F</b> : more answers of low effect ( <b>Q</b> ). <b>M</b> : protection of nursery and spawning areas is deemed necessary ( <b>Q/L</b> )
Stronger enforcement/monitoring (e.g., cctv, observer on board, EU fisheries compliance fleet) and charges for failure	High	No	<b>F</b> : more answers of low/no effect, there were comments that controls and fines were already strict ( <b>Q</b> ). <b>M</b> : more answers of high effect, although difficulties related to monitoring due to the extent of the coastline and the multiple points of landings were highlighted ( <b>Q</b> ), weak control and enforcement have resulted in low compliance ( <b>L</b> )
Involve more the fishing sector in discard mitigation proceedings	High	High	<b>F/M</b> : measures of more involvement of the industry and raising awareness were considered effective. Answers varied mainly from Medium to High. Fishers have felt that have been ignored/not been considered so far ( <b>Q/L</b> )
Raise awareness among all parties (citizens, industry etc.) about discarding	High	Medium	

“**M**” indicates marine scientists, “**F**” indicates trawl fishers and sector’s representatives. Measures were scored using a scale (from High to No effect). The last column offers some key comments regarding evidence from the qualitative assessment (**Q**) and literature review (**L**)

\*Fish from sustainable stocks which are not subject to landing obligation and conditional that the supply chain is primed, and a consumer habit alteration targeted campaign is in place

Regarding the creation of a market in principle, the measure was seen positively by most of the participants. Fishers expressed views such as “Commercializing species is a high effect measure, however, bringing benefits to the fisher too is the most important incentive,” “The most important incentive that needs to be given to the fishers is to be able to take advantage of the discards either selling these to the

consumer (subject to nutritional training, new recipes) or to the food industry/processing (e.g., fish sticks etc.) as long as there is a market for those and a demand has been created.” However, specific concerns have been also raised such as “If landing obligation leads to using discards for supplying the processing industry and aquaculture with bait, it will create competition in fresh fish as it will reinforce the quality of



fish from aquaculture ... since there will not be a profit for fishers and there is already competition among aquaculture and fishers. I would prefer the landing obligation to reinforce the fisher's status, so the fisher is able to sell the discards in the market as long as the nutritional habits of consumers have changed." Concerns about increasing the pressure on stocks, if cheap landings were to be provided to other industries (e.g., aquaculture, pharmaceutical), have been expressed in de Vos et al. (2016). An insight into this measure is also provided by Sigurðardóttir et al. (2015) who employed a SWOT analysis and engaged 13 experts in European fisheries science that covered a comprehensive view of discards, both across EU regions and across issues. Findings showed that commercializing unwanted fish as a mitigation measure for discards reduction provides strengths and opportunities translated to improved profits and public image when more catch is being utilized. Associated weakness is the cost involved in improving markets, for example, due to the need for change in social attitude and taste, which should be coupled by rigorous science to safeguard the sustainability of the stocks. The largest threats included absences of management tools or knowledge for newly targeted species and the risk of over-fishing previously non-target species. A further risk identified in the "Fishing for the Markets" project (2011) in England was the increase of imports if the supply chain was not primed before demand was created.

Furthermore, more involvement of the fishing sector in discard mitigation proceedings, raising awareness, and use of financial incentives (e.g., cost compensation) were also supported most of the times from both sides. With regard to more involvement, it was highlighted by fishers that "Fishers care about the quality and health of the environment and should work together with other stakeholders," "The industry has not been considered so far in the new regulation." Similarly, in de Vos et al. (2016) study, through interviews and focus groups, the general sentiment was that Greek fishers feel ignored in the policy process and targeted by the measure of landing obligation. Focusing on co-management as a mitigation measure for discards reduction, Sigurðardóttir et al. (2015) in their SWOT analysis identified strengths and opportunities such as better adapted management measures, increased voluntary compliance, better/more detailed data, and mutual respect. Weaknesses included the need for careful design of the cooperation to each situation and the risk of eroded co-management structure if incentive structure changes or leading figures disappear. Evidence shows that co-management and regionalized fisheries management are considered success factors of implementing the new policy (Santiago et al. 2015; de Vos et al. 2016). Raising awareness across all parties (citizens, industry, etc.) about discarding is seen as an important support measure for both scientists and fishers, especially in developing new markets. However, risks

such as ending up in too simplistic methods by involving more people without sufficient knowledge and losing voices of key stakeholders in campaigns of radical greens/fishers have also been reported (Sigurðardóttir et al. 2015).

Overall, financial incentives in our study are seen positively in reducing unwanted catches. In particular, regarding subsidize more selective gears, provide for free materials, and cost compensation for fish landed, most scientists were supportive especially for the first, while concerns were also expressed: "The landing obligation should not be linked to financial incentives. The ecological effects of such a measure should be carefully monitored, especially from a spatial point of view." Financial incentives to support prevention of captures, handle landings, and cover extra cost were favored across fishers as also demonstrated by statements such as "To increase the selectivity wherever is possible is a good solution, but it requires to support the industry. To improve detection is also important and it should be subsidized so that the whole industry can use it, and not only fishers/owners with greater purchasing power," "A payment to the fishermen (average price) for the landed discards should be established," "Cost should be covered not only to adjust the vessel but also for infrastructure on land for keeping discards," "Apart from subsidizing more selective gears and provide for free materials to fix/replace damaged gear, it is necessary to cover operational expenses of trawling in order to secure discards (labour expenses, cost of gear and its maintenance) and achieve high implementation of the regulation." Similarly, in Eliassen et al. (2014), Greek trawlers operating in a mixed fishery would expect to be compensated by the market or state in case of a discard ban. However, regarding subsidizing, more selective gear fishers also expressed the view that "Selectivity is already high no more tools are needed, the focus should be on economic incentives," "In a multispecies fishery it is very difficult to take efficient and effective technical measures. The capture of juveniles in drag (which is the main problem of discards in my opinion), since the introduction of the square mesh of 40 m /m diamond or rhomboid 50 m/m, has been drastically reduced." With regard to the last statement, in Eliassen et al. (2014), Greek fishers saw discards as an unavoidable part of the fishing practice in a mixed fishery and regarded that gear selectivity has improved recently as in the 40-mm square mesh, discards of commercially relevant species below the minimum legal size constitute a small amount of the catch.

Furthermore, respondents provided input regarding the most important combination of interventions that they deemed necessary so that the landing obligation can successfully be met in their country (open-ended question). Marine scientists highlighted combinations that included mainly spatio-temporal regulations and monitoring with for example financial incentives, increase awareness, and involvement of the sector. Representative quotes include "It is necessary to develop regional or local management plans that combine spatio-

temporal closures and improvement of technical measures to increase gear selectivity considering spawning periods or migrations. It is very important that all measures involve fishermen and take greater account of their experience at sea. Boost sales of all products derived from legal fishing by improving the marketing of lesser-known or non-appreciated species. The measures to be adopted must differ among fleets according to the gear, season and target species,” “The financial measures will be the most effective if combined with monitoring ... The effectiveness of monitoring and regulation has been proved to be of medium effect due to the extent of the coastline and the multiple points of landings ... it is regarded that financial measures will be possibly more effective as long as there will be an ‘indirect subsidy’ of fishing,” “The following three points are of importance: i) the spatio-temporal and effort regulations are the most important that can be implemented in the trawl fishery. The improvement of gear selectivity is also necessary although it could have less success, since the trawl fishery is a multispecies fishery with many sizes and different body forms; ii) the involvement of the fishing sector in the accomplishment of elimination of discards by means of management plans in each zone (port, or fleet) and iii) continuous monitoring on the landings and discards and sizes. These will be the three main pillars in the discards elimination ... a system similar to that carried out in Iceland, which promotes ‘do not fish’ undersized target species by specific measures at short time ... alternative uses for unwanted fish (e.g., fishmeal, bait) and use the benefits in the reduction of discards (unwanted fish), research in discards’ reduction to promote a strategy considering technical, biological and fishery’s aspects. Improvement and enhancement of infrastructure with regards to maintenance of fish in good conditions and also avoiding market fluctuations, reduction in prices, etc.”

Fishers emphasized the need for financial incentives in their combined measures that included also “de minimis” solutions for the minimum sizes, more control by the authority, and involvement of the sector. However, they expressed concerns about fleet reduction such as “Implementing combined measures is the best solution regarding the regulation ... however, this may lead to further fleet reduction,” “We should not adopt measures that in the past have not worked ... and although the fleet has been reduced the impacts are moderate.” Statements like the last one demonstrate also the importance of evaluating measures. Overall, it seems that combinations of measures are more likely to contribute to the effective implementation of the new regulation considering also the issue of scale (from local, regional to national) and fishery involved. Findings from a SWOT analysis on Mediterranean discard ban carried out in an important Spanish port where different stakeholders were involved (fishers, administrators, NGOs, scientists, and entrepreneurs on the regulation) showed that a combination of management measures, including spatio-temporal

fishing ban (protection of nursery and spawning areas) and improved gear selectivity, can guarantee the main ecological and socio-economic goals in a sustainable fisheries framework (García-Rivera et al. 2015). However, as the authors note, the main constraints regard the creation of meaningful and agreed incentives to adopt selective fishing practices (García-Rivera et al. 2015). Other findings of the study were that the overall sentiment was negative regarding the implementation of the new CFP and that penalties for failure of this requirement were not still clear in the Mediterranean.

Finally, other interesting points that were raised during our study were that discards reduction was not perceived unanimously as a major issue by involved fishers in line with some evidence from literature review (e.g., Zhou 2008; Eliassen et al. 2012, 2014; Heath et al. 2014). This belief linked to community/social factors is expected to impact on the decision to discard, while more awareness about the negative impacts of discarding may even change the views of some fishers within the community. Expressed views included the following: “There are other issues like temperature, contamination, plastic litter... that affect fisheries instead of discards,” “I believe that discards reinforce the food chain of seabirds and fish and help the ecosystem. Therefore, any change regarding environmental impact should be explored,” “I would rather discard in the sea than landing as in this way we conserve a food chain in the ecosystem (food for seabirds and fish). If not, we will create a new industry chain which will create new interests and problems.” In addition, apart from the above concerns (e.g., need for facilities and increasing competition across marine sectors such as aquaculture vs fisheries), it was also reported that the “industry needs to collect its own data for example, regarding stock assessment,” demonstrating the importance of exploring social connections between fishers and the regulator.

## Discussion and conclusions

Market demand is a strong driver of discarding in Mediterranean fisheries, while various factors (environmental, social, and institutional) act in a synergetic way. Importantly, it seems that at fisher level, reliance on economic drivers alone to reveal discarding behavior may be inadequate. Social factors as well influence behavior and hence the success of the employed management strategy. These may include social norms and values (e.g., perceived legitimacy of measures, perceived impacts of discarding), individual socio-demographic and psychological characteristics of the fisher (e.g., reluctance to change, van Putten et al. 2012), level of trust among fishers, between fishers and the regulator (Grafton 2005), and others that need to be further explored.

Based on the range and interrelation of drivers and factors of discarding, different measures and incentive mechanisms

have been considered to reduce discards following the landing obligation. For example, spatio-temporal restrictions and gear selectivity target environmental drivers (e.g., nursery grounds and species characteristics). Raising awareness could impact on market and consumers' preferences as well as on fishers' social values and norms. More involvement of the fishing sector in the process of reducing discarding could also impact on social factors and the link between fishers and the regulator improving compliance. Different financial incentives could impact on different drivers and factors. For example, by subsidizing more selective gears, environmental factors are taken into consideration by preventing captures at the first place, while cost compensation for fish landed aims to reduce the level of discarding once caught through fisher's short-term economic driven decision-making.

In this study, we also emphasize that the success of fisheries management is strongly dependent on targeting modification of behavior. This change could be enhanced through encouraging (e.g., use of financial incentives), engaging (e.g., from more involvement of the fishing sector in the process to co-management), enabling (e.g., create demand and infrastructure for landings, raise awareness), evaluating (e.g., the effectiveness of existing measures such as gear selectivity, spatio-temporal restrictions), and exploring local contexts, social capital issues of the involved fisheries, and skippers discarding behaviors.

Findings from our engagement with marine scientists and fishers from the three countries revealed that both sides feel strongly about the involvement of the industry in the process of reducing discarding, the need to raise awareness across different parties, and the use of some sort of financial incentives. Regarding the latter, scientists were more in favor of subsidizing gear and "indirect subsidies," while fishers would expect to be compensated for the cost involved in landing fish (e.g., as in Eliassen et al. 2014) suggesting financial incentives related to the cost of equipment and vessel adjustments, infrastructure on land, operational expenses, and an average price for the landed discards. As far as the measure of commercializing unwanted fish is concerned, it raised concerns. For example, fishers pointed out the lack of infrastructure (e.g., "services and buildings in the harbors"), the potential competition in fresh fish, and benefits for other marine sectors than the fishing industry. Concerns about the sustainability of the stocks have been also highlighted in the literature (e.g., Sigurðardóttir et al. 2015; de Vos et al. 2016). These issues as well as additional for example, the cost involved in changing social attitude, absences of management tools or knowledge for newly targeted species, and prior establishment of the supply chain (Fishing for the Markets' project 2011; Sigurðardóttir et al. 2015) should be considered if such a measure is to be materialized.

It is also important to emphasize that fishers felt strongly the need to be considered in the new regulation along

with other stakeholders as also expressed in de Vos et al. (2016). Successful management should incorporate the skill sets and knowledge of interested stakeholders (fishers, scientists, and managers) (O'Keefe et al. 2014) and in particular fishers since they have unique knowledge concerning local features, needs, and better understanding of impacts of measures (Vassilopoulou et al. 2012). Other points are that some of the fishers did not perceive discards reduction as a major issue as also seen in literature (e.g., Eliassen et al. 2012, 2014), while concerns about further reduction of the fleet due to multiple measures were expressed. These are points to be further explored and addressed in a framework of action for reducing discards in the basin that takes into account human behavior, especially considering the challenges involved in enforcement and monitoring (e.g., high cost, multiple landing points, extent of coastline). Non-convergence to spatio-temporal restrictions, enforcement, and monitoring might be related to a need to deviate from traditional measures of avoiding discards and a need for evaluation of existing measures (as in Vassilopoulou et al. 2014). Nevertheless, although specific challenges have been mentioned, these measures are preferred among scientists especially in combination with other so that the landing obligation can successfully be met.

Regarding measures, the challenge is how to achieve compliance with the new requirements, while enabling fishers to continue to operate profitably, considering that no policy can totally eliminate economic incentives to discard (Pascoe 1997). Particularly in the Mediterranean due to its specific characteristics, related to the heterogeneity of the area in terms of species diversity, fishing techniques, and practices, along with its economic structure (STECF 2006), reducing discards is a complex issue. Overall, mitigation tools of discards in the Mediterranean trawl fisheries mainly include technical specifications aiming at the selectivity improvement and measures aiming to reduce unwanted catches, such as spatio-temporal closures. However, evidence from this exploratory study shows that socio-economic measures such as raising awareness across stakeholders, more involvement of the fishers in the new regulation, and financial incentives could be explored further as potential contributing interventions to reducing discards. Overall, combinations of different management and incentivizing tools designed for specific fisheries and fleet characteristics that may differ between regions (Hall and Mainprize 2005; Johnsen and Eliassen 2011; Uhlmann et al. 2013) are expected to be more effective. Therefore, future research should focus on successful synergies while considering scale and fleet variability. Furthermore, it is noted that best practices from elsewhere could be used and the effectiveness of such measures could be explored through pilot projects. The contribution of European funds

like that of European Maritime and Fisheries Fund (EMFF) could be an important enabling factor to test solutions (McIlwain 2015) especially during a time of economic difficulty in most Mediterranean countries.

Importantly, the focus of work should be towards creating a framework that guides the modification of behavior and therefore exploring the link between management options, social outcomes, and behavioral responses (van Putten et al. 2012). However, in order to achieve that, human behavior should be acknowledged as an important source of variability to be further explored. In this context, there is need for more socio-economic evidence and tools that offer an insight into how people use, appreciate the marine environment, how they impact on it, and how they react to new and different forms of governance. Social scientists could contribute towards that direction in various ways, for example, by informing modeling approaches, exploring tools and measures that can influence positively human behavior, of not only fishers but also consumers, enhancing inclusion of multiple stakeholders and co-management through tailored participatory processes that create interactions across fishers, scientists, and policy-makers, and increase accountability and compliance. However, till integration of socio-economic evidence is further developed, policy-makers and regulators should be alert to limitations to support their decision-making.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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