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How can discards in European fisheries be mitigated? Strengths, weaknesses, opportunities and threats of potential mitigation methods

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ABSTRACT

A number of solutions, with varying efficiency, have been proposed to mitigate discards. In this paper twelve mitigation measures were reviewed by their strengths and weaknesses, along with opportunities and threats, they might entail. How mitigation methods could either support or counteract others was also reviewed. The analyses of the mitigation measures are based on expert knowledge and experience and supported with existing literature. Discarding is highly variable and is influenced by numerous biological, technical and operational factors as well as social and economic drivers. These influences need to be carefully considered when designing management approaches. Finally, all reforms must be carefully considered within the context of a broader management system. The full management system needs to be thought of coherently to create an incentive framework that motivates fishers to avoid unwanted catches. It is only in this setting that discard mitigation methods may be potentially effective.

1. Introduction

Over recent years the global fishing industry has been under increasing pressure to reduce bycatch and discards [1]. Discarding, where a portion of catch taken by a fishing vessel, is returned to the sea dead or alive [2], has drawn increasing criticism from the public and non-governmental organisations, such as the Fish Fight campaign in the UK and other European countries [3]. Discards are seen by many as a waste of human food and economic resources, and a source of unaccounted mortality as long as this catch is unreported and mortality rates of releases uncertain, increasing the uncertainty of stock assessments. It has been argued that discarding is not just an artefact of non-selective fishing practices, but also a consequence of clumsy management regulations [4]. For example, until 2014 the European Union (EU) fisheries regulations prohibited the retention of catch that exceeded landing quotas or contravened Minimum Landing Sizes (MLS), and prescribed catch compositions [5]. Catches will also be discarded if they are of poor quality, small size, or of a non-commercial species or a low market value [6]. Discarding small-sized individuals of target commercial species to save quota for larger, higher priced individuals is referred to as high grading. In EU fisheries, high levels of discards have been considered an issue for decades [7]. The elimination of discarding and unwanted catches has been identified as a main objective under the 2012 reform of the Common Fisheries Policy [8–10] and a discard ban will be introduced gradually between 2015 and 2019 for all regulated species in European waters.

Discarding levels in EU fisheries vary between locations, gears, species and fishing grounds [11]. For example, the discarded proportions in trammel net fisheries vary between 20% in the Northeast

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Atlantic to 40% in the North Sea [12,13]. Similarly, proportions discarded by trawl fisheries will vary with fishing ground, and also between trawl types [11,14]. Northeast Atlantic pair trawlers discard from 40% to 60% of their catch, while single bottom trawlers discard between 20% and 40% of their catch throughout the Northeast Atlantic [12]. In the Mediterranean, discard ratios from bottom trawlers show high differences among areas and operations, varying from 20% to 65% [15]. A study combining data collected via the data collection framework indicates that there is a high difference in discard levels between the Mediterranean Sea and other regions in the EU and overall the variation in discard ratios for a number of commonly-discarded species is often greater between regions than between fisheries [11].

The substantial amount of catch that is discarded in some EU fisheries warrants the development and implementation of discard mitigation methods. Herein, actions carried out by a management authority (e.g. the EU Commission, a member state or a fisheries organisation) with the aim of reducing or eliminating discards within a fishery, will be referred to as mitigation methods. Surely, already proven approaches hold some potential for further discard reductions [16]. These include, but are not limited to, technical measures; minimum mesh sizes, effort regulations, and catch quotas [17]. Reviewing these and other examples, also of non-European fisheries, supported by relevant literature a detailed evaluation of potential mitigation methods are provided and possible options are identified for European Union Member States to meet the objectives of the reformed Common Fisheries Policy (CFP). Using a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis, what factors may influence the success or failure of a measure are examined, and how different methods may interact to increase the likelihood of success. For example, the involvement of fishers in the development and adoption of more selective fishing gear [18] or the emergence of new markets for traditionally-discarded species or sizes [19,20].

SWOT analysis is a tool mainly used in business management to identify Strengths, Weaknesses, Opportunities and Threats of a business. In SWOT analysis the analyst lists factors regarding the business into four categories; internal positive and negative factors (strengths and weaknesses) and external positive and negative factors (opportunities and threats). These lists can be used to build a business strategy and identify ways of using strengths and opportunities to outweigh or circumvent weaknesses and threats. The number of areas using SWOT is constantly increasing [21]; including applied fisheries science [22]. Here SWOT analysis is applied to each of the identified discard mitigation approach to achieve a comparative description of the strengths and weaknesses of each approach.

However, because reasons for discarding are diverse and intricate [23], mitigation methods cannot be implemented in isolation; they should be combined with other methods to achieve a comprehensive approach suited to the conditions in the fishery of interest. Therefore, the analysis examines how different discard mitigation methods can be combined into a consistent strategy in light of their respective strengths and weaknesses. A comprehensive and generic approach to designing a discard mitigation strategy is proposed.

2. Material and methods

2.1. Mitigation methods

During an expert workshop held in Reykjavik, Iceland in May, 29–31, 2012, twelve mitigation methods were identified and classified into five categories. The suggested mitigation methods along with their description and classification are listed in Table 1:

a. Total allowable catch (TAC) and quotas: controls how much is allowed to be caught (catch quotas), or landed (landings quotas).
b. Fishing effort and capacity: limits the amount of fishing activity, such as the size of the fleet, amount of time spent fishing or amount of gear deployed.
c. Technical: a range of regulations that define how, where and when fishing occurs, as opposed to (a) and (b) which affect the quantities of fish and fishing.
d. Social: methods and initiatives that affect the relationships between and perceptions of stakeholders, in particular fishers.
e. Market: actions and initiatives that modify the way fish are sold along the supply chain, from the vessel to the end user.

2.2. SWOT analysis

The SWOT analysis was also carried out during this workshop. Thirteen experts participated with expertise in European fisheries science, and together covered a comprehensive view of discards, both across EU regions (from the Mediterranean to the North

Table 1
A list of the mitigation methods with description and a classification.

No.	Mitigation measure	Description	Category
1	Multi-species catch quota	Limiting the catch of a mixed species group, as opposed to single species quotas.	TAC and quotas
2	Catch quotas, not landing quotas	Limiting catches instead of landings.	TAC and quotas
3	Fishing effort and capacity	Introducing or modifying limits to fishing effort and/or fleet capacity.	Fishing effort and capacity
4	Temporary/spatial restrictions	Restricting particular/all fishing activities in a certain area and/or for a defined time.	Technical
5	Selective practices	Prescribing types of gear and devices, or other practices better suited to avoid unwanted catch whilst maintaining commercial catch rates. Selectivity can be based on fish size, shape, species and/or behaviour.	Technical
6	Change of Minimum landing size (MLS)	Introducing or modifying MLS, the minimum size at which a fish can be landed.	Technical
7	Catch composition	Changing the proportion of non-target marketable catches allowed to be retained.	Technical
8	Discard ban	Requiring to land all catches of defined categories.	Technical
9	Transferability of quotas	Introducing or modifying the rules of lease, acquisition or swap of quota for specific species.	Technical
10	Co-management	Directly involving stakeholders in research, development and implementation of discard mitigation methods. May occur at different levels, i.e. stakeholders as consultants, partners, delegation or leaders.	Social
11	Society awareness of discard issues	Changing the awareness of stakeholders regarding discarding and discard related issues – may include e.g. education.	Social
12	Improving existing and/or finding new markets	Improving existing markets and finding new markets for species which are not currently utilised; this may include products for human consumption, fish meal, pharmaceuticals and other industries.	Market

Table 2
Strength, weaknesses, opportunities and threats of 12 discard mitigation methods.

Mitigation measure	Strengths	Weaknesses	Opportunities	Threats
Multi-species quotas	Reduces quota related discards. Robust to short-term variation in biomass of those species that are within the framework of the mixed-species quota. Provides fishermen with more flexibility in achieving viable catch compositions reducing the level of selectivity required in the fishing methods.	Will not address discards driven by factors other than quota. With a cap on total landings you might not get as high landings.		Fishers might target the most valuable species and could potentially discard the less valuable species to maximise short-term earnings.
Catch quotas, not landing quotas	Means that the fishers are accountable for their total catch, not only the landings. Eliminate quota driven discards. The monitoring required to enforce catch quotas would generate better data on size distribution and fishing mortality, thus improve stock assessments	Requires monitoring the catch rather than only the landings; if using CCTV or full coverage surveillance to achieve this, it will be expensive In a full monitored catch quota system many species can turn out to be choke species. Some because of weak stock situation, other because of mismatch between TAC and actual abundance.	Fishers should aim for highest economical revenues and therefore choose more selective fishing gears. ITQs based on total catch instead of landings may decrease the incentive to discard as a catch quota setting, discards would count against the quota. Transferability of quotas can smooth the quota distribution and use, and prevent fishing stop due to choke species	Lack of detailed information about discards at current state. CCTVs may be resisted by fishers or even contravene their fundamental rights. Abilities to circumvent CCTVs or other monitoring schemes.
Changing fishing effort and capacity	Restricting number of days at sea is easier to enforce than many other measures. Long term economic profit if stock increases.	Fishers will resist unless offered compensation. With limited time at sea fishers may opt to use less selective fishing methods, or be forced to fish in areas of high abundance of unwanted species/size classes	Could create incentive for fishers to improve catching efficiency (e.g. by using selective gears) to maximise landings. Increased economic efficiency of the fishery.	Increased likelihood of unemployment rate amongst fishers and onshore workers on the short term. Risk of unstable supply.
Temporary/spatial restrictions	Adaptable and can work in real time. Can serve as a buffer against management errors and recruitment failure. Long term economic profit if stock increases. Supports use of co-management when fishers are made responsible for reporting to support real time closures. High level of compliance when supported by satellite monitoring.	Has resulted in extensive fishing on the closed area borders, such as the plaice box Requires robust information on spatial distribution and population structure of fish stocks. Needs to carefully reflect a species distribution and abundance pattern in time and space, otherwise risk that discards just move to areas where fishing pressures have been transferred. Difficult to enforce without VMS or similar monitoring technology.	Reduced supply of fish to markets, because of closure, can lead to higher market price. Closure might incentivize fishers to explore new and rich fishing grounds. Creates incentives amongst operators to use selective gears when access is conditional to the gear deployed.	If not all fishing gears are prohibited in an area, the other ones also generate discards and might benefit from it and no gain is made in the end. If not all gear types are excluded from fishing this might create non-compliance due to feeling of unfairness. Possible income loss when fishers are kept from their usual fishing grounds having to move further distances and could threaten less mobile fleets which are less able to move to new fishing grounds. Risk of unstable supply.
Selective practices	Decreased discard mortality. With selective gears income can be increased because of better quality of catch and reduced cost for fuel for some towed gears, moreover, revenue from quotas can be maximised where unwanted fish are counted against quota Improves efficiency of fishing vessels by reducing man-hours taken to sort the catch. Improving selective properties of gears does not affect fishing opportunities. Long term economic profit if stocks increase.	Costly for fishers and government to develop and implement. Fishers don't like using selective gear if their profits are compromised by a loss of marketable fish. Some selective innovations can be deemed to be illegal when fishing net designs are legislated for.	Bridging the gap between environmental and economic issues. Increased probability of getting an eco-label. Adopting more selective fishing methods can warrant better fishing opportunities and improve positions during negotiations for fishing opportunities.	Too high species-selectivity can make fishers vulnerable to quota reductions.
Change of MLS	Lowering MLS could substantially decrease MLS-driven discards. With lower MLS and favourable market profits would increase with knock-on economic benefits.	Shifting to a target of smaller fish could impact negatively on the stock and result in loss of profit in the long term. Different MLS for different species causes difficulties in multi-species fisheries.	Opportunity to match MLS with selectivity parameters or marketable sizes.	

Table 2 (*continued*)

Mitigation measure	Strengths	Weaknesses	Opportunities	Threats
Change/remove catch composition regulations	Designed to make sure that the correct gear types are employed for targeted species and to prevent inappropriate gears that would lead to higher discards/catches of small/juvenile fish Changing regulation to fit actual catch composition could reduce regulation related discards.	Can generate discards of marketable catches, when defined catch composition is not reflected by catches taken with specified gear. Additional complexity in recordkeeping. Changes in catch compositions driven by relative changes in population abundance can become incompatible with defined catch composition.		If this method is legislated with too little flexibility, discards might not be eliminated because of variation between vessels.
Discard ban	If unwanted catch is sold at a sufficient price there would be additional revenue. The monitoring required to enforce a ban would generate better data on size distribution and fishing mortality, thus improve stock assessments.	Landing this otherwise discarded material could come at a financial cost to fishers. A larger part of the catch would need to be sorted onboard and handled in the landing ports. In the absence of other supporting measures, it doesn't solve problem of unwanted catch being caught. Increased fishing mortality since some discarded animals survive. Storage and processing space needed for otherwise discarded species. High level of enforcement needed; costly.	Opportunities for new markets for formerly discarded species/size classes. A discard ban is expected to encourage fishers to fish more selectively.	Without markets for previously discarded species, biological waste on the harbours might increase. Lack of sufficient infrastructure to handle material.
Transferability of quotas	Adding transferability to IQs decreases discard proportion. Increasing transferability of quota allows fishers to match quota composition to their catch composition.	High leasing prices compared to catch value can increase discarding. Requires costly IT systems.	Increased transferability and documentation of quotas may support traceability of catch.	Increased transferability might disconnect quota trade from fishing opportunities.
Co-management	Fishers' experience and knowledge helps to develop management measures better adapted to local or regional conditions. Co-managed system results in fishers increased sense of ownership of management methods, which increases voluntary compliance.	If incentive structure changes or leading figures disappear, the co-management structure can erode. Cooperation between fishing industry and management need careful design to be appropriate for each situation.	Can lead to better/more detailed data provided to managers. Mutual respect between fishing industry and managers.	
Society awareness of discard issues	Provide a forum for knowledge of different stakeholders to be highlighted Society awareness can form a basis for developing new markets which can absorb otherwise discarded species and sizes			More people involved without sufficient knowledge may result in methods that are too simplistic. Increased awareness can lead to campaigns of radical greens/fishers where voices of key-stakeholders can get lost.
Improving existing markets/finding new markets	Profits from otherwise discarded material to the industry and knock-on economic benefits. Good for the public image of the fisheries to utilise a larger part of the catch.	The infrastructure must be in place or needs to be developed. May require a change in social attitude and taste. (This could also be an opportunity.) Could increase fishing mortality on species/size classes of fish that would have otherwise survived the discard process.	Creates an incentive for landing more of the catch, thus allowing collection of more accurate data. Regionalising markets to respond more seasonally to what's out there in the sea.	For the new targeted species you might not have the management tools/knowledge. Could increase fishing pressure for new species or size classes beyond sustainable levels. New markets might disturb existing markets.

Atlantic, from the Baltic Sea to Iceland) and across issues (technology, onboard observer programmes, discard quantification and analysis, management). Participants were divided into three quadruplets. The expert workshop served as initial brain storming to identify the main SWOTs of each measure. Following that, all authors worked by correspondence and contributed the relevant literature to substantiate the expert judgements. For each mitigation method, the SWOT analysis was applied with respect to three dimensions: environmental, socioeconomic and compliance, which were later on collapsed in Table 2. By analysing each measure with respect to these dimensions, the aim was to obtain comprehensive coverage of discard management issues. All three dimensions have systematically been examined for each mitigation measure and, for simplification the results are combined.

3. Results

Table 2 summarises the results of the SWOT analysis of each mitigation measure where the three dimensions are collapsed together. The following sections cover the main results from the SWOT analyses per mitigation measure as listed in Table 1, along with information on how each mitigation measure could be complemented by others.

3.1. Multi-species catch quotas

Multispecies quotas, classified as TAC and quotas, apply to mixed species groups and offer a potential tool to solve the discard problem in multispecies fisheries. Multispecies quotas are used in the US Northeast Atlantic shelf [24] and could be useful in the North Sea, according to model simulations [25]. In a European context, mixed-species quota management is not wide spread. Currently, ICES provides mixed-fisheries advice only for the North Sea [25,26]. The first two mixed fisheries working groups (2010 and 2011) were considered experimental, but the last one (2012) is being considered by ACOM as an official assessment.

The main strength of this management measure is that it provides a consistent view across all species caught in a mixed fishery, and it is robust to short term variation in biomass of those species that are within the framework of the mixed species quota. If species fluctuate in different ways within the species mix, this should reduce quota driven discards. On the other hand, potential weaknesses at this moment are that knowledge on its implementation is limited and also its effect on short-term profitability. Regarding compliance, mixed-species quota may give higher legitimacy in the system than single species quotas, although there is a need for a new system of control and enforcement. Co-management is essential in devising the way mixed-species quotas are implemented.

3.2. Catch quotas, not landing quotas

Implementing catch quotas as opposed to landing quotas, is a TAC and quotas measure that involve limiting catches instead of landings. Implementing this measure could provide better data for scientific assessment and management [19] because total removals would be known, rather than having to be estimated from discard sampling programmes and logbooks, provided the measure would be actually enforced and complied with. In connection with this strength and opportunity, its major weakness is that monitoring the total catch might require the costly implementation of a fully-documented fishery (e.g. via electronic or traditional observer-based monitoring) [27]. Under a full documented catch quota, a mismatch between TAC and actual fishing opportunities can close whole fisheries, as they can not be adjusted by discard as today [28]. Without a full documentation of the fishery, deriving a meaningful catch quota from existing landings quota would be difficult due to uncertainties in current discard estimates and in the way fisheries are going to adapt their strategies to the new regulation. Simply adding estimated discard fractions on top of landings may be over simplistic, considering the high variability in discard ratios; besides, the measure might aim at incentivizing more selective practices and avoiding previously discarded catch. In that case, a reduction in total catch would need to be implemented.

Transferability of quotas should be enabled under a catch quota regime, making it easier for fishers to get a hold of a quota for the species that end up in their nets. This could reduce the economic impact of catch quotas.

3.3. Fishing effort and capacity

In most cases, reduced fishing effort will result in decreased catch, thus reduced discards if the discarded fraction remains constant. To reduce the pressure of fishing on fish stocks by reducing days at sea is easy to enforce [29]. The decrease in discards in UK fisheries between 2002 and 2008 has been largely ascribed to a reduction in fishing effort and total catch [30]. This fact is also apparent worldwide as reported by Zeller and Pauly [31], where they argue the recent discard decreases are mainly explained to sharp declines in worldwide catches and not for better fishing practices. The general problem with limiting effort and capacity is the constantly increasing fishing power owing to technical progress, which results in effort and capacity limits being efficient only on the short term. Surely, reducing fishing effort would reduce discarding for all species but in a fishery with a mix of healthy stocks and stocks in poor condition it has been considered an inefficient tool [23]. One of its weaknesses includes the short-term loss of income for fishers, and its threats include increased likelihood of higher unemployment rate amongst fishers and onshore workers. Effort regulations under catch quota management system where total removals from each stock are documented can be unnecessary and the topic of removing them under such a management scheme is worth discussing. If effort regulations are removed under an enforceable catch quota management system fishers are allowed to exert all the effort they want, on the condition that once one species quotas is fished up (choke species) the fishery is closed – which may result in less predictable limitations of effort.

3.4. Temporary/spatial restrictions

Temporary and/or spatial restrictions are widely used technical mitigation methods and have shown to be effective in many fisheries [32]. They involve restricting a portion or all fishing activity in a certain area permanently or for a defined period. In the context of mitigating discards, they are usually applied to “hot spots” of juveniles or to nursery grounds during a particular period of the year. It is a simple mitigation measure with high compliance when monitored by Vessel Monitoring Systems (VMS) [33]. Although it has increased stocks in some instances [6], in other cases it did not have the expected effect, such in the North Sea “plaice box” with slower juvenile growth rates [34]. Temporary and/or spatial restrictions can work well in combination with other mitigation methods such as selective practices. This type of mitigation methods can be used to encourage fisher's use of more selective gear, for example by allowing specific types of gears in an otherwise closed area [6]. Closing larger areas to fishers not equipped with a given selective device prompted a strong incentive to use the selective device in Norway [35]. The downside to this mitigation measure is the shift of fishing effort to other areas which have to be considered carefully before implementation [36].

Abad et al. [37] showed how fishing restrictions due to post-oil spill *Prestige* management measures can affect the pattern of fishing effort exerted on three species of great commercial value in northern Spain: the anglerfishes *Lophius piscatorius* and *Lophius budegassa*, and the mackerel *Scomber scombrus*. This was done to detect shifts that could be due to either the oil spill per se or the management methods taken to minimise pollution effects. Results showed a spatial displacement of fishing effort to other fishing areas in the case of anglerfish, and the transfer of fishing effort between different fishery units in the case of mackerel. Both effects were caused primarily by the management measures in force after the oil spill. This example shows how a management measure can prompt other kinds of indirect effects that remain often unknown, so it is necessary to evaluate the likely positive or negative impact of these side effects [16].

In multispecies fisheries one could fear that places and times appropriate to avoid discards of one species might result in increased discards of other species; these multispecies effects largely remain to be investigated.

To avoid the risk of displacement of fishers to another area, these mitigation methods could be complemented with controlled fishing effort and capacity. When vessels are displaced from an area with a closure, there may be a mismatch of its existing quota but transferability of quotas could help solve that problem. Lastly, to improve acceptability, temporary/spatial restrictions could be implemented within a co-management approach that incorporates fishers' inputs [38–40]. They know much about areas and times to avoid to reduce discards. Moreover, they likely would prefer to discuss their fishing strategies than having them imposed upon them.

3.5. Selective practices

Modifications to certain types of gear, the use of specific devices, or modified practices may all have the common goal of avoiding unwanted catch whilst maintaining or even increasing commercial catch rates. Such improvements in selectivity can be based on fish size, shape, species or behaviour [41,42]. These technical mitigation methods has been shown to reduce discard levels [14,43–45]. However, improving selectivity can be a double-edged sword because unaccounted mortality may not necessarily cease if escaping organisms experience similar levels of mortality as what is observed for discards [41,46,47]. Also hyperselectivity can alter ecosystem functioning, as some particular species or specimen sizes are removed in a sharp target way, potentially causing a gap in trophic relationships of the ecosystem [48,49].

Regulating selectivity is usually connected to other mitigation methods. For instance, MLS regulations are often not in accordance with regulations on selectivity leading to discarding of fish under MLS [35,50–52]. When it comes to compliance, there are examples where MLS regulations failed because fishers rigged their gear in a way that reduced the selectivity to prevent small fish from escaping [53,54] to avoid short-term economic loss [16,20,55]. Selective devices may also be gradually modified to suit fisheries-specific operations which compromised their efficiency in discard reduction [56]. Additional factors that reduce the uptake of new selective designs include: the economic costs associated with new technologies [20,55,57] and the perceived increase in the burden of work and/or risk when operating more complex gear [20,51,55]. Furthermore, when losses of marketable catch occur, effort may increase to compensate for the loss, thereby modifying the consequences of discard reduction [16]. With that in mind, co-management is needed to develop best practices in selectivity as no-one knows the gear better than fishers themselves.

3.6. Change of minimum landing size

Minimum landing size (MLS) regulations are a substantial driver of discarding in the EU [23,44,58,59] and elsewhere [60]. Decreasing MLS is a technical measure that has the potential to decrease discarding [14]. However, any decrease in MLS needs to safeguard that the capture of juvenile pre-spawners is sustainable. Some of the benefits and effectiveness of the existing MLS regulations have been doubted for various reasons [61,62]. Managers must ensure that gear regulations determining size selectivity are in line with defined MLS [14,35,50,51] (see also section 3.5). This is more problematic in multispecies fisheries but can be supported by the use of species selective devices [41,43,51].

Lowering the MLS may increase the relative proportion of individuals of legal size in the catch. If combined with a discard ban, changing or even removing MLS regulations might be beneficial depending on the nature of the ban.

3.7. Catch composition regulations

Catch composition regulations are technical methods meant to limit the landings of sensitive or depleted bycatch species by setting the maximum proportion of non-target marketable catch that may be retained onboard. These regulations limit the landings, not the catch, and are therefore strong incentives to discard under the current CFP, and instead of reducing discards they exacerbate the problem [63]. If a majority of species have catch quotas, the purpose of catch species composition regulations will be non-existent. Otherwise, fishers will have to actively avoid areas or periods where species with low/no quota availability occur, or implement species selective gears, to avoid the onset of a *choke* species. *Choke* species are those species for which the entire TAC has been caught, preventing the fleet from keeping fishing other species, and thus from achieving optimum yield. Under a CFP consisting of catch quotas and a discard ban, it is proposed to get rid off catch composition regulations [2].

3.8. Discard ban

Imposing a discard ban is a technical measure that requires all catches to be landed for all or a prescribed suite of species. The measure is meant to encourage fishers to fish more selectively. A gradual elimination of discards has already been put into force under the new EU Common Fisheries Policy [64].

A potential weakness of a discard ban is the high cost of enforcement, as it might require for successful implementation full observer coverage or electronic video monitoring to validate a self-reporting system [27]. Another practical problem arises when storage space on board the vessel that would have previously been used for storing marketable species, could be taken up by non-marketable catch. Iceland and Norway have both imposed a discard ban. In Iceland's Individual Transferable Quota (ITQ) system there is flexibility such that when a vessel overfishes or brings in some amounts of bycatch, or species controlled with quota allocation, the company has a certain time period to obtain additional quota thus creating an incentive to land the whole catch. In addition, a certain percentage of bycatch, is allowed to be landed and all the revenue from the sale of those catches will benefit research. In Norway, there is no option of buying additional quota once catch has been landed; it is the skipper's responsibility to ensure that the vessel has quotas to participate in a given fishery. If the bycatch turns out to be too high, the vessel must move to other fishing grounds [65].

Transferability of quota could be helpful in enforcing a discard ban (see above for Icelandic example) if done under an individual quota scheme. Raising awareness on issues related to discards is changing perception of the public and favors the implementation of a discard ban. Improving existing markets could also facilitate compliance with a discard ban. If there is a market for previously discarded fish an incentive might be created to land a greater portion of the catch.

3.9. Transferability of quotas

In landing quota systems, quota-regulated species that are caught in the absence of quota have to be discarded or fishing must cease under a discard ban. A transferability of quota between vessels in the form of opportunity to lease, buy or swap quota for specific species, is a technical measure that would prevent discards of quota-regulated species and help to create incentives to keep catch that would otherwise be discarded, given a decent market price. However, this measure needs a strong framework to operate properly. Such a system has been implemented in Iceland, but Icelandic stocks are exploited by a single nation and relatively few operators. The Icelandic

ITQ system offers a good deal of flexibility such that if a vessel catches fish without a quota, the company has some time after landing to obtain quota (see discard ban section above). This creates the needed incentive to land the whole catch. When ITQs were launched in New Zealand there were some indicators that discards increased soon after its implementation since fishers did not get enough compensation for the bycatch for it to be worthwhile to land [66].

Transferability of quota has been introduced by some EU member states and proposed in the new Common Fisheries Policy. An EU study on right based management concludes that it is still difficult to determine the effect on discarding [67]. The study contains cases from UK, France and Denmark where transferability of quotas seems to reduce quota related discarding. In all cases, swapping or renting quotas is mediated by producer organisations (POs) or similar organisations [68]. This indicates that the quota market should entail low transaction costs, since it is already institutionalised close to the users.

3.10. 0. Co-management

There is no single definition of co-management, which is classified as a social measure. It generally involves collaborative and participatory processes in regulatory decision-making [69] and can be defined as arrangements where responsibility for resource management is shared between the government and user groups. The use of co-management in discard mitigation proceedings provides an effective platform for: (a) knowledge exchange that can help shape the requirements of discard reduction methods to fit specific fisheries and discard problems; (b) higher acceptability, thus easier implementation of discard reduction methods if they are decided in co-operation with the involved fishers (or other stakeholder); and (c) improved legitimacy of the regulations and specific methods among the fishers and thereby higher compliance.

The EU Commission has recognised the problems of top-down management and proposes a higher degree of co-management for the coming years [70]. Co-management may result in more sustainable fisheries [38,71], provided a number of conditions are in place, such as adequate institutional settings, clear incentives and social capital in the form of community leaders/key persons. Co-management is therefore not a simple tool to implement, and needs to be incorporated into existing historically-formed institutional structures and traditions for cooperation.

3.11. 1. Society awareness of discard issues

Society awareness of discards is a social measure that involves increasing the awareness of stakeholders regarding discarding practices and discard related issues. This goes beyond awareness just among the fishers and includes the market chain of buyers and retailers, environmental NGOs, fish consumers, and more broadly citizens. This could occur through various channels, new or existing institutions, for example, the FishFight campaign which claims to have made a positive impact on supermarkets, the EU government, the fishing industry and the public sector [3]. On the other hand, over simplistic messages might confuse the public and/or create conflicting perceptions among the public and the stakeholders.

The strengths of increased society awareness are clear as more consumers would strive to make the right choice when it comes to buying fish, such as buying previously less commercial species or supporting local markets.

3.12. Improving existing or finding new markets

The idea behind finding new markets or improving existing ones to mitigate discards is to create an incentive to land a larger portion of the catch ('land more'), in particular for species which are not currently utilised. This may include products for human consumption, fish meal, pharmaceuticals and other industries. The SWOT showed that this mitigation measure demonstrates mostly strengths and opportunities, both as profits from otherwise discarded material and as improved public image when a larger part of the catch becomes utilised. Because a new market may change the status of a species from non-target to target, a potential weakness is that improving markets might prove costly; especially as marketing a new species may require a change in social attitude and taste. The needed shift in perception needs to be carefully introduced and backed up by rigorous science to safeguard the sustainability of the stocks. The largest threats are considered to be the potential absence of suitable management tools or knowledge for a newly targeted species, and the incentive to increase effort and/or catch to take profit from the new markets, with the risk of over-fishing a previously non-target species.

Improving markets needs to be supported by increasing the awareness of society to the possibility of using currently discarded catch for human consumption or other products. Increasing awareness may help to raise demand, improving markets and therefore incentivising the landing of a greater proportion of a vessel's catch; including anorganic materials such as plastic and rubbish.

3.13. Guidelines on how to design comprehensive discard mitigation strategies

To increase the usability of these results for policy makers, guidelines for designing a comprehensive discard mitigation strategy are derived from the results of the SWOT analysis above (Table 2). Patterns and reasons for discarding are very variable among, and even within, a given fishery, among species, seasons, or years [52]. On the other hand, no single mitigation measure can address all kinds of discards and all reasons for discarding. Therefore, to reduce discards, *ad hoc* approaches must be developed that rely on a thorough understanding of the discards and their drivers in the fishery of interest. This requires an analysis of discard patterns such as the one carried out by Uhlmann et al. [11], an examination of indicators such as by Catchpole et al. [30] and an analysis of factors at community level influencing discards. These analyses constitute the context for implementation of discard mitigation methods [72]. Models to determine discard drivers could also be useful in the process [52,72]. With the aim of reducing discards and maintaining economically and environmentally sustainable fisheries, the following process is suggested for managers:

1. Describe the fishery, in particular looking at discard patterns and indicators.
2. Analyse which drivers are in place in the market, regulations as well as community perspective, and if the drivers interact in influencing discard behaviour, pattern and level.
3. Establish a suite of mitigating methods designed to address the most important drivers or combinations of drivers. The analysis and formulation of the set of methods could be in some form of co-management with stakeholders to gain knowledge and legitimacy of the set up.
4. Implement mitigation methods, in collaboration with stakeholders.
5. Monitor and evaluate the effect of the mitigation methods.
6. Identify gaps involving stakeholders in the process and develop new methods to increase efficiency.
7. Repeat 1–6.

4. Discussion

The SWOT analysis in this study proved to be a useful tool for reviewing discard mitigation methods. It suggested that mitigation

measures become more successful in achieving their goal when used in combination, rather than isolation which is in line with the findings of O'Keefe et al. in an assessment of different discard mitigation measures [73] Nevertheless, it also demonstrated that most measures may have (unwanted) spin offs and ask for adaptive management approaches. Co-management was repetitively scored as a strength, making it a core ingredient for a successful approach to develop and implement reduction strategies.

The use of the SWOT analysis in the context of fisheries, might be applicable for assessing any type of policy changes within a group of experts. Inviting stakeholders, such as inspectors, policy makers and/or operators to take part in a SWOT analysis might deepen and strengthen the analysis. SWOT analysis helps organising a discussion and a common evaluation, and thereby may soften discussions and conflicts when there are important stakes. The key was to think of every measure in a systematic, consistent way. However, when it comes to integrating methods, SWOT analysis was not sufficient and a complementary approach was needed. As for analysing the different dimensions, economic losses and opportunities are expected to be a substantive motivator for changing behaviour, so it proved important to account for the social context in which mitigation methods are placed [16]. SWOT analysis is useful for a comprehensive overview of the many available mitigation methods such as presented in this paper but is too simple for preparing actual implementation. However, it is too simple to easily deal with analysing mitigation methods that have very diverse effects in different scenarios. That would require separate SWOT analyses to get useful information. Difference in views of experts from Northern Europe and Southern Europe was evident, for example compliance in their respective regions. Other notable differences were different consumer preferences in terms of species and sizes, which may lead to different discarding practices and solutions. The findings reflect that the discard situation varies between the different European countries. Having a diverse group of scientists strengthens the study resulting in a comprehensive European analysis, covering the different perspectives from the Northern and Southern countries.

It is also worth considering that some of the proposed reforms may involve destabilising some of the management systems currently in place, and thus may worsen the ecological impacts of discards rather than improving them. There is a risk in oversimplifying the introduction of such reforms, with lack, or misuse of, scientific information; for example there is a risk of setting catch quotas too high, thereby increasing fishing mortality, or too low, jeopardising the fleets' profitability. Therefore current conditions in a fishery must be carefully taken into account before any implementation.

The results of this study should and will hopefully prove a useful reference for fisheries managers, *e.g.* for implementing the new CFP which is in place since January 2014, and in other settings. The new policy includes an obligation to land all catches which will be implemented in a stepwise manner to an increasing number of fisheries, and species within each fishery. The obligation to land will be associated with catch quotas. Minimum conservation sizes (MCS) will be established for each species, and the use of catches below MCS will be restricted to purposes other than human consumption (*e.g.* fish meal, pet food, or cosmetics). Obligation to land associated with catch quotas should create strong incentives to adopt more selective gears and practices, since unwanted bycatch will (i) count against quotas, (ii) occupy space in the hold, and (iii) have low value, especially the small-sized component, given the MCS provision reported above. However, the latter provision might impair one of the potential strengths of a discard ban – an increase in revenue. Also it is unclear how the new regulation will address the need for fully documenting catch, which is required for this kind of regulations to be complied with.

The new CFP is also going to include a provision for regionalisation, by which member states concerned by fisheries in each region and Advisory Councils will be more directly involved in the implementation details for these methods. The proposed framework could be a direct input for the regionalised fisheries management to implement the rules of the new CFP in a way adapted to the regional specificities.

The SWOT evaluation applied to individual methods here was based on experience; the examination of their compatibility was more speculative, relying on theoretical expectations. Indeed there is little experience in the field, and surprises can be expected. Many mitigation methods are going to be used and combined as regional discard management plans are going to be negotiated and implemented under the new EU CFP. The process will provide many opportunities for managers and fishers to learn by doing, and for scientists to observe and evaluate further how discard mitigation work.

5. Conclusion

In this study the strengths and weaknesses of twelve different methods to mitigate discards have systematically been reviewed and the opportunities and threats they might involve have been identified. The findings include that discarding is highly variable and depends on numerous variables which are biological, technical and operational as well as socio-economic drivers. This should be carefully considered, as not reflecting this variability in management approaches may involve risk of failure. Finally, all reforms must be carefully considered with a current management system as a whole in mind. For example, the former EU management system generated many incentives to discard. The whole management system needs to be thought of coherently to reduce or eliminate these incentives. It is only in this setting that discard mitigation methods are potentially effective.

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