Fish-X

D2.6. Summary & Best Practices on Discards – WP 2

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Abstract	Discarding, the practice of returning unwanted catches of species and/or size of targeted species to the sea, is widely recognised as a major obstacle to fisheries sustainability. It has both environmental and socio-economic negative impacts. In the EU, the Common Fisheries Policy establishes a discard ban, also known as the “landing obligation”, which sets as a principle that seafood caught is kept onboard and unloaded at port, i.e., “landed”. The paper highlights that the EU legislative framework to prevent discarding remains poorly implemented due to multiple and sometimes intertwined drivers relating to both selectivity and monitoring, control and surveillance issues. Lessons learned from past digitization initiatives show that new technologies offer significant prospects to successfully address the discards.

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Acronyms and abbreviations

Abbreviation	Meaning
AIS	Automatic identification system
CCTV	Close-circuit television
CFP	Common Fisheries Policy
EFCA	European Fisheries Control Agency
eCDT	Electronic catch documentation and traceability
EU	European Union
FAO	Food and Agriculture Organisation
FRA	Fisheries Restricted Areas
GIS	Geographic Information Systems
GFCM	General Fisheries Commission for the Mediterranean
IUU	Illegal, unreported and unregulated (fishing)
LO	Landing obligation
MCS	Monitoring Control and Surveillance
MLS	Minimum Landing Size
MPAs	Marine Protected Areas
MSP	Maritime Spatial Planning
OECD	Organisation for Economic Co-operation and Development
REM	Remote Electronic Monitoring
SDI	Spatial Data Infrastructure
SSF	Small-scale fisheries/fishers
STECF	Scientific, Technical and Economic Committee for Fisheries
VMS	Vessel Monitoring Systems

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Executive Summary

This paper has been developed in the framework of the Horizon Europe FISH-X' project Work Package 2 "Assessment/Roadmap". It fulfills Deliverable 2.6. "Summary & Best Practices on Discards": "*A paper will be developed and shared with the whole consortium on best practices regarding discards. The main goal will be to provide a reliable feedback of the regulation relative to discards. The paper should make diagnoses and propose alternatives or recommendations for improvements*".

The paper focuses on the implementation of the European Union (EU)'s discard regulation, known as the "landing obligation". It explores how new digital technologies can support the implementation of the EU discard ban.

The paper shows that the EU legislative framework to prevent discarding remains poorly implemented. The analysis of main rationales for discarding in EU fisheries indicates that the practice results from multiple and sometimes intertwined drivers relating to both selectivity and challenges with monitoring, control and surveillance.

A review of digitisation programmes dedicated to addressing the problem of discarding in European fisheries demonstrates that new technologies offer significant prospects to successfully address the issue. The FISH-X project namely aims at making use of tracking devices to improve monitoring and control of EU fisheries and to display the information collected through a geoportal. A specific attention was therefore paid area-based technologies. Both the best practices and shortcomings of past projects addressing discards in the EU should now be leveraged to increase effectiveness of currently-available solutions and influence the development of future ones.

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1. Introduction

In marine fisheries, discarding is the practice of returning unwanted catches of species and/or size of targeted species to the sea as a result of economic, legal or other considerations.[1] According to the Food and Agriculture Organisation (FAO), fish and other animals thrown back at sea, both dead and alive, count as being discarded.[2] In 2019, the FAO estimated that about 9.1 million tonnes of fish are discarded annually.[3] According to the Organisation's 2022 State of World Fisheries and Aquaculture, 80.1 million tons of fish were caught at sea in 2019.[4] This means that about 11.4 % of global marine fishery catches are discarded. Discarding is very closely related to bycatch, which the FAO defines as "*the catch of organisms that are not targeted. This includes organisms that are outside legal-size limits, over-quotas, threatened, endangered and protected species, and discarded for whatever other reasons*".[5]

Discarding has negative effects both from ecological and socio-economic perspectives. The European Commission considers that discarding "*constitutes a substantial waste of resources and negatively affects the sustainable exploitation of marine biological resources and marine ecosystems and the financial viability of fisheries*".[6] Overall, discarding is increasingly and globally perceived as unjustifiably wasteful and many States have or are adopting discard bans.

From an ecological perspective, discarding damages fish stocks by killing juvenile individuals before they reach reproductive age.[7] This reduces stock biomass and negatively affects the potential for stocks to rebuild.[8] Discarding also impacts the broader structure of marine communities. For instance, discarding alters marine food chains "*by generating increased levels of food through dead fish or fish that may not survive after release, altering the relative prey-predator abundance and causing additional interactions between species*".[9] Additionally, unrecorded discards of protected and/or threatened species such as marine mammals, sharks and rays, seabirds and turtles undermine conservation efforts.

From a socio-economic perspective, a fishery without unwanted catches is more efficient in time and labour, as fishing effort is not wasted sorting catches.[10] Furthermore, when unrecorded, discards hinder sound scientific fisheries assessments. This contributes to overfishing and prevents the sustainable management of fish stocks, thereby negatively affecting both marine ecosystems and fisheries. Overfishing, in turn, also increases the time needed at sea to catch the same amount of fish, thereby increasing operational costs such as fuel and labour.[11] According to the FAO, "*discards of small specimens also entail a reduction in future harvesting opportunities, which reduces the growth potential of the stock as well as potential yields from the fishery, with obvious economic consequences*".[12] Discarding has also been raised as a major concern amongst the European Union's (EU) citizens, both as a

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waste of food and natural resources, and as a practice that contributes to degrading the marine environment.[1] As such, this practice also damages the image of the fisheries sector, both in the eyes of consumers and citizens.

Discarding practices are deeply intertwined with the issue of illegal, unreported and unregulated (IUU) fishing. First, discarding unwanted catches directly qualifies as unreported fishing.[13] At a global level, it is estimated that approximately 30 % of all unreported catches are discarded at sea.[14]

The present paper explores how new digital technologies can support the implementation of the EU discard ban, also known as the landing obligation (LO). To do so, it answers the following set of sub-questions: *How does the EU intend to address discarding? What are the results of the policies currently in place*? *Why those results? How can new technologies help? What's next?*

The paper summarises the relevant European legislative framework and shares key figures to assess its current level of implementation (Section 1). It analyses the main rationale behind persisting discarding practices in EU fisheries by looking both at challenges in gear selectivity and Monitoring Control and Surveillance (MCS) (Section 2). The paper then examines key digitisation projects recently conducted in the EU to demonstrate how new technologies can successfully address the practice of discarding (Section 3). It concludes by discussing key findings from the review of those case studies and makes recommendations for ongoing and future digital initiatives dedicated to eliminating discarding in EU fisheries (Section 4).

[1] For instance, the High Level Panel for a Sustainable Ocean Economy, which gathers 17 countries, representing 44% of the world's EEZ, and 25% of the world's fisheries, had adopted the action "Minimise bycatch, discards, and waste in seafood supply chains" in its 2030 agenda. https://oceanpanel.org/the-agenda/ocean-wealth/

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2. Discards in EU Fisheries: from goals to reality

2.1. The objective of a discard-ban in EU fisheries: the "landing obligation"

The EU has set up a specific legislative framework to address the issue of discard. Article 5 (a) of the Common Fisheries Policy (CFP) says that "*the CFP shall, in particular gradually eliminate discards, on a case-by-case basis, taking into account the best available scientific advice, by avoiding and reducing, as far as possible, unwanted catches, and by gradually ensuring that catches are landed*".[15] CFP Article 15 introduces a discard ban. According to Article 15, fishers have the obligation to land all catches ("the landing obligation" - LO) of species which are subject to catch limits and, in the Mediterranean Sea, also catches of species which are subject to minimum sizes.[16] The landing obligation came into force in 2015, with a phase-in approach that ended in 2019. According to the European Commission, the objective of the landing obligation is "to eliminate discards by encouraging fishers to fish more selectively and to avoid unwanted catches". [17]

A number of exemptions to the landing obligations were also set up. It does not apply to species in respect of which fishing is prohibited. The landing obligation does not apply to species with a high survival rate or when unwanted catch is too difficult or costly to avoid. So-called *de minimis* exemption of up to 5 % of the total annual catches in cases where selectivity increases are difficult to achieve or where handling unwanted catches entails disproportionate costs. Those exemptions are granted in the framework of multi-annual plans, discard plans, or delegated acts.

CFP Article 15 - Landing obligation

"1. All catches of species which are subject to catch limits and, in the Mediterranean, also catches of species which are subject to minimum sizes as defined in Annex III to Regulation (EC) No 1967/2006, caught during fishing activities in Union waters or by Union fishing vessels outside Union waters in waters not subject to third countries' sovereignty or jurisdiction, in the fisheries and geographical areas listed below shall be brought and retained on board the fishing vessels, recorded, landed and counted against the quotas where applicable, except when used as live bait [...]".

Regulation (EU) 2015/812 of the European Parliament and of the Council was adopted in 2015 to adapt multiple fisheries policies to the newly introduced landing obligation. Specific amendments were especially made to Regulation (EC) No 1224/2009 (the "Control Regulation") to ensure the effective implementation of the landing obligation. A new Article 73.a "Control observers for the monitoring of the landing obligation" was inserted in the Control Regulation. It states that control observers may be deployed by Member States for the monitoring of the landing obligation.[18] Failure to comply with the landing obligation also becomes a serious infringement subject to sanctions under revised Control Regulation Article 90 (1)(c).[19] The EU also adopted so-called discard plans, delegated regulations at sea basins level conceived as temporary measures designed to gradually phase-out discards and to put in place the landing obligation.[20] Besides, the EU funded dedicated research projects aiming at

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supporting the implementation of the landing obligation and reducing discards and bycatch, including the "Discardless"[21] and "MINOUW"[22] projects.

2.2. The reality of large-scale persisting discards in EU fisheries

The landing obligation remains poorly implemented in the EU. In fact, "*the Commission's audits and the initiatives of the European Fisheries Control Agency (EFCA) indicate a general lack of compliance with the landing obligation*".[23] In 2021, a survey indicated that the majority of the fisheries stakeholders interviewed across several EU sea basins believed that non-compliance with the landing obligation was occurring.[24]

Due to widespread unreported and illegal discarding, global and fleet-by-fleet data on discards in EU waters is still sparse, lacking or unreliable.[25] Nonetheless, and taking into account that those fishing areas are shared with non-EU countries, discarded fish would amount to around 1.5 million tonnes annually in the North-East Atlantic, and to 250 thousand tonnes annually in the Mediterranean and Black Sea.[26] According to the best available data, 4.26 million tonnes of fish were landed in the EU in 2019, with reported landing of discards amounting to 229 205 tonnes.[27] Based on this data, the discard rate in the EU would therefore equal to about 5.1 %.[2] This figure however should be treated cautiously as a 2022 WWF report demonstrates that not all reported landings in the EU have known discards data.[28] In fact, across all fleet segments the percentage of fleet data with associated discard data that is neither zero nor confidential is 14.3 %.[29] This means 85.7 % of all EU landings are left without transparent and robust data on their discarding practices.[30] In fact, the Scientific, Technical and Economic Committee for Fisheries (STECF) itself recognizes that "*the quality of discards estimates cannot be assured and should be used with caution, as these estimates might be uncertain and biased*" due to the poor quality of the discard data submitted by EU Member States.[31] Overall, the European Commission believes that "there is extensive, illegal and undocumented discarding of catches in several sea basins".[32]

The EFCA produced reports for compliance with the landing obligations in the Baltic and North Seas, as well as for North Western Waters and Pelagics in the North Sea and North Western Waters. The EFCA reports are all the more interesting for discard assessments because these compliance assessments used illegal discards as a proxy of compliance. In Baltic waters, EFCA observed that in most pelagic fleet segments (targeting herring and sprat) there was high compliance with the landing obligation over the study period (2017 – 2018) and lower compliance levels estimated for fixed and towed gears catching place and for towed gears targeting cod.[33] In the North Sea and North Western Waters, non-compliance with the LO appears to have been widespread during the evaluation period for certain towed gears used in certain areas.[3435] High discard rates were identified for Pelagics in the North Sea and North Western Waters.[36] According to the EFCA, this suggests a high level of non-compliance with the LO in these fleet segments, in particular for pelagic trawlers.[37]

[2] According to the FAO, the discard rate is the proportion of the total catch that is discarded. The formula to calculate discard rate is as follows: Discard Rate = Discards / (Landings + Discards)

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No report was produced by EFCA to assess discards from EU fisheries or the implementation of the landing obligation in the Mediterranean and the Black Sea. According to the FAO (2022), 1.39 million tons of fish were captured in the Mediterranean and Black Sea in 2019.[38] In 2019, commercial fisheries were still discarding at least 275 000 tonnes per year in those sea basins (FAO, 2019).[39] As landings and discards are known, an average discard rate for the Mediterranean and Black Sea can be calculated for 2019.[3] Based on the best available data it would amount to at least 16.5 %.

On 30 May 2018, the European Commission initiated an update of the EU Fisheries control system, including a revision of the Control Regulation. One of the key objectives of the Control Regulation revision was to address the compliance dimension of discards and strengthen the implementation of the landing obligation. To this end, the Commission proposed the introduction of new measures, such as the use of remote electronic monitoring (including close-circuit television - CCTV), as well as amendments to articles referring to monitoring, control and surveillance (MCS) tools such as Vessel Monitoring Systems (VMS). The revised text is currently still being negotiated in trilogues between the European Commission, the European Parliament and the Council.

[3] The formula to calculate discard rate is as follows: Discard Rate = Discards / (Landings + Discards).

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3. Analysing discards in EU fisheries

The EU discard legislative framework remains poorly implemented. Key drivers of discards in EU fisheries are analysed to better understand such a situation.

According to the European Commission, discarding usually occurs when the fish is smaller than the legal size, of low market value, or damaged, as well as when the fisher does not have a quota for it, or because it is prohibited to catch that species.[40] The analysis of discards in fisheries can be considered from two angles. First, it requires understanding why unwanted fish were caught, i.e., the selectivity approach. In turn, selectivity can be approached through multiple facets, ranging from why fish are caught by accident to why fish may come to be considered as bycatch. Another approach is to understand why discarding *can* happen. This points out to the Monitoring, Control and Surveillance (MCS) dimension of the issue. Both the selectivity and MCS approaches are considered in the specific EU context.

3.1. EU discards through the selectivity lens: why are some unwanted fish caught?

Discarding directly derives from fisheries selectivity. When an unwanted catch is thrown overboard, this can first be explained by the fact that it was caught while not being targeted. When it comes to catching non-targeted species by accident, selectivity varies greatly across fishing practices. In short, some fishing techniques are more likely to lead to bycatch and associated discards compared to others. Due to their less selective nature, some fisheries, such as those using trawls, have higher chances to experience situations where their haul might contain both targeted and bycaught species. Likewise, unselective fishing practices expose fishers to catching target fish that will have size issues, while some fishing techniques may also be likely to damage the fish more compared to others, then making it difficult to commercially exploit.

To get a more granular understanding of vessels' capacity to target the desired species, one can look into how some fleet segments are more affected than others. This would mean they may have practices or face specific issues likely to foster discard. To do so, length is sometimes used as an explicative variable. In the EU, vessels of 0-12 metres in length show a discard rate of 17 %, vessels of 12-18 metres in length display a 21 % discard rate, vessels between 18 and 24 metres a 24 % discard rate, while the fleet segment above 24 metres in length has a 12 % discard rate.[41]

However, the "size approach" remains too limited to understand the issue of discard. For instance, let us consider vessels above 24 metres in length. In 2019, this fleet segment was responsible for the largest total amount of landings, 2.67 million tons. They were also responsible for the largest recorded discards, more than 80 000 tons. Despite these figures, the discard rate of this fleet segment only amounted to 12 %. In comparison, vessels below 12 metres landed the smallest amount of fish in the EU (less than 50 000 tons), and were also responsible for the lowest amount of discards amongst all EU fleets, with below 20 000 tons recorded. Yet, with 17 %, their calculated discard rate was higher than those of vessels above 24 metres. While the fleet segment above 24 metres in length would be responsible for more than four times more discards than vessels below 12 metres in absolute terms, their discard rate would also be 5% lower. This clearly shows that figures relating to size can be used

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to tell different stories in EU fisheries. This, in turn, implies that size is not the best criteria to understand discard, and that other factors are most likely at play. Further to this, in some areas, fishing practices are highly variable amongst size-segment fleets. For instance, so-called small-scale fisheries in the Mediterranean are characterised by multi-species and multi-gears practices, making it very difficult to consider it as a homogeneous size-segment. This also calls for analysis going beyond the simple indicator of size.

Beyond vessel length, what would really matter when it comes to understanding discarding is the fishing technique. In fact, in the EU, the 2022 WWF study found that vessels using active bottom-contacting gears would amount to 92 % of recorded discards.[42] This aligns with what EFCA finds in their landing obligation compliance reports[43]. They point out to generic bottom trawls, otter trawls and seines as well as both towed and fixed gears for groundfish species for the North Western Waters and the Baltic and North Sea. According to the FAO (2019), in the Mediterranean and Black Sea, "*demersal trawl fisheries produce almost half of [discards], whereas discard rates for pelagic fisheries, such as pelagic trawls and purse seiners, are generally lower than those for bottom trawls. Information on discards in small-scale fisheries is relatively scarce, but available data (mainly for trammel net and gillnet) show a discard rate lower than for other fisheries*".[44] At a global level, the FAO estimates that bottom trawling fisheries would be responsible for about 46 % of total annual discards.[45] A qualitative analysis using the 2019 FAO discards report's data also demonstrated that unwanted catches are very weak to weak for passive gears, but moderate to strong for active gears.[46]

Focus on the Mediterranean

While EFCA has not produced any landing obligation compliance for the Mediterranean, a 2014 academic paper offers a glimpse into the distribution of discards in the area. The study by Tsagarakis et al. (2014) collected quantitative information concerning fisheries discards in the Mediterranean Sea to produce discard ratios for various EU and non-EU fleets.[47]

For the EU bottom trawl fleets considered (Spain, Italy, Greece), the data from the article allows us to calculate an average discard rate of 37.53 %. For rapido trawl, data available from fleets in Italy (Adriatic Sea) shows an average discard rate of 57.6 %. For the rapido trawl fleet targeting scallops in shallow waters, the discard rate even goes as high as 90.4 %.

For EU nets fisheries, available data (Spain, Italy, Greece: trammel nets and gillnets) shows an average discard rate of 17.6 %. For EU long-liner fleet studies (Greece: Aeagan), the discard rate amounts to 3.2 %. For the two European traps fleets studied (Italy: Tyrrhenian Sea and Adriatic), the average discard rate obtained is 5.3 %. For the two boat seines fisheries considered (Croatia, Greece), the average discard rate is 19.25 %. Lastly, European small-scale mixed fisheries studied (Spain, Croatia, Greece) display an average discard rate of 4.7 %.

This paper clearly shows that trawlers have much higher discard rates compared to other European fisheries in the Mediterranean. Authors also highlight that "*trawls are responsible for the bulk of discards in the Mediterranean notwithstanding their relatively low contribution (15 %) in total landings*".

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Arguably, the paper dates back from 2014, but the general lack of compliance with the landing obligation nonetheless suggests that the current situation is most likely quite similar to what was observed at the time.

Difficulties to catch the desired targets can be exacerbated due to natural factors. According to Tsagarakis et al. (2014),

Life cycles of species greatly affect the catch composition and accordingly the discarding process. Increased discarding of some species has been reported during their reproductive period when they migrate to shallow areas accessible to small-scale fisheries, thus larger quantities are caught and subsequently discarded (Tzanatos et al., 2007). In addition, during the recruitment period of target species when large quantities of small individuals are caught, broad discarding may take place (Sánchez et al., 2004; Tsagarakis et al., 2012). Seasonal patterns in discarding have been observed in several fisheries (Moranta et al., 2000; Castriota et al., 2001; Quetglas et al., 2004) and they are possibly related to species life cycles and/or changes in distribution grounds.

Furthermore, other environmental factors are also suspected to contribute to discard, including depth and associated consequences on fish including their biomass, substrate/seabed type[48], currents, etc. of the fishing area.

3.2. Beyond selectivity: why are some fish unwanted?

Understanding discarding however requires exploring rationale going beyond “catching non-targeted species”. It is necessary to go beyond the selectivity approach to understand why a given fish caught turns out to be unwanted in the first place. If everything could be kept onboard or considered worth keeping onboard, then there would be no such thing as “unwanted catch” to begin with. With no unwanted catch, there would be no reason to discard. In fact, to fully grasp reasons to discard, it is necessary to understand why some catch is considered as unwanted in the first place. This points out to practical, economic and legal drivers of discard.

First, selectivity matters because not everything is allowed to be caught in the first place. When facing a situation where, due to a lack of selectivity, the haul brings in species caught without the necessary rights, discarding appears as an easy way to get rid of the evidence. It can be the case because the species is protected and should not have been caught in the first place. For species with fishing rights, catch can still be illegal, for instance when juveniles/undersized individuals are caught. In mixed fisheries, it can also be the case when the target species is harvested alongside fish species they have run out of quotas for, so-called “choke species”. When the fishers have no other options than either catching both target species and their associated choke species that become de facto bycatch when they are out-of-quotas, or nothing at all, they can decide to still put the haul at sea, and use discarding to get rid of the choke species. In all of those situations, the legal framework constitutes the indirect driver of discard. The law, not the fisher, makes it that the catch qualifies as bycatch, and creates the necessity to discard.

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In the EU, the growing complexity of discards rules, especially regarding the establishment of exemptions, appears as a key obstacle to the implementation of the landing obligation. Fitzpatrick et al. (2018) observed that "the trend towards complexity has strengthened with a significant increase in both the number of exemptions sought and the number of supporting documents", while "the complexity is largely due to industry appeals for exemptions".[49] In turn, "complex rules, combined with uncertainty at the management level, are translated into confusion and inaction at the operational level and create a significant barrier to implementation". Decrease in discard data from fishers is also observed in certain sea basins.

In fact, both the multiple requests for exemptions and the lack of data on discards would be used as ways to try avoiding closure of mixed fisheries in the face of choke species issues. In a multispecies fishery, different species caught in the same haul will have different quotas. Fishers may face a situation where a species quota is exhausted, while others are not. When discarding is allowed, fishers can simply continue fishing by discarding the surplus of catch of the species whose quota is exhausted. With the landing obligation and the discard ban, the "choke species" is the species with the smallest quota. The quota exhaustion of such choke species leads to fisheries closure, since it is no longer possible to discard the over-quota choke species excess to continue fishing other species.

Now, let's consider the context of a catch compliant with the law, meaning when discarding is not used as a way to hide IUU fishing activities or breaches of fisheries management and conservation measures such as harvesting protected or out-of-quotas species by accident. In such a context, there are still many reasons leading to a need for selectivity. From a practical perspective, space onboard is a key driver of discards in that not everything that is caught can be physically kept onboard. Due to space limitation, fishers have to choose what to keep, or not. The rationale behind this choice then explains discard. In a market economy, the economic value of the catch constitutes a key rationale for space allocation. In practice, even when the fish was legally harvested, fishers can be tempted to make use of discarding in order to make room for more economically valuable catches. This practice is commonly known as "high-grading" and occurs in EU waters. For instance, the EFCA's compliance reports indicate that "there was evidence of significant high-grading of cod" in the North Sea.[50]

In turn, issues of "high-grading" point out to the market dimension of discard. Adopting a "market approach" highlights how dynamic a practice discarding is. In fact, a given species might very well be subject to discarding at a certain point of the year, and being retained onboard at another time, because its value on market has fluctuated in the meantime. For instance, it has been demonstrated that the availability of resources, sometimes affected by the status of the stocks, has been shown to affect fluctuations of market demands and associate discarding practices in several cases in the Mediterranean Sea.[51] Many reasons can in turn impact the value of fish in markets, providing an equal number for discarding or not. For instance, transfer of species from the "discards" to the "landings" fraction have been observed towards the end of the fishing season, when cumulative fishing pressure may have reduced resources.[52] Likewise, discards observed in some fisheries were lower in winter because market prices increased due to the decrease in catches as a result of bad weather.[53] Besides, discarding varies not only due to the evolving intrinsic value of a given fish, but also to its relative value compared to other species. As the relative value of fish species "A" or "B" varies, so does the rationale to

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keep either the species “A” or “B” onboard. For instance, in the Mediterranean, Tsagarakis et al. (2014), recall the example of the late 1980’s anchovy stock crise, which increased the economic value of this fish species, and led to an increase of discards for other fish such as sardines. In the Mediterranean, the cost of disposal of unwanted catch and the creation of a black market for juvenile fish would nowadays constitute the main obstacles to the implementation of the landing obligation.[54]

Lastly, according to the FAO, overfishing also indirectly “*contributes to discarding through declining average sizes of fish captured which make the catch less marketable and hence more likely to be discarded*”.[55] As discarding itself directly contributes to overfishing, this constitutes a vicious cycle. Persisting overfishing in a number of EU stocks[56] makes it likely that this phenomenon also impacts EU fisheries.

3.3. EU discards through the MCS lens: why *can* they be caught?

Another approach to why discarding still happens in the EU is that it is permitted due to issues to monitor and control the implementation of the landing obligation. According to the European Commission, “*the continuing problem of discards is caused primarily by a lack of control and enforcement by Member State authorities and must be addressed within the EU’s fisheries control system*”.[57] In 2021, EU fisheries stakeholders themselves pointed out the lack of efficient control tools at sea and the inadequacy of current control measures, combined with the fact that the landing obligation is not accepted by the industry, to explain the non-compliance with the landing obligation.[58]

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4. Addressing EU discards through digital technologies: a state of the art

This paper feeds into a Horizon Europe research project supporting digitization for small-scale fishers. This section seeks to understand how digital technologies and tools have been used so far to address the issue of discards and what are the lessons learned, with a specific attention to those targeting SSF.

Considered approaches to address discards through new digital technologies will twofold. First, from a selectivity perspective, solutions to avoid unwanted catches derive from changing fishing tactics and strategies. For instance, this includes identifying those areas/seasons where bycatch is more likely to happen, based on a better understanding of marine ecosystems and their interaction with fisheries through digital tools. Although feeding into the selectivity approach, improvement of fishing techniques, i.e., by looking into gear technology, are not considered in the scope of this paper. Second, from a law enforcement perspective, MCS solutions can also be developed to better identify and discourage occurrences of illegal discards.

4.1. Digitization in a fisheries context

To scope this research, it is necessary to define what is meant by "digitization". Digitization is defined by the Organisation for Economic Co-operation and Development (OECD) as "the adoption of information communication technologies, including the Internet, mobile technologies and devices, as well as data analytics, to improve the generation, collection, exchange, aggregation, combination, analysis, access, searchability and presentation of digital content, including for the development of services and applications".[59] In a fisheries context, digitization will especially refer to electronic catch data collection systems (e-log books, and any relevant use of technological tools such as smartphones), and electronic monitoring systems or Remote Electronic Monitoring (REM), including CCTV, sensors in the nets, also sometimes encompassed into "Fully Documented Fisheries" programmes - together with spatial data collection tools such as satellite vessels detection systems (automatic identification system -AIS-, VMS). Where relevant, other technologies based on satellites and data tools (e.g., ocean modelling) can also be considered.

4.2. Addressing discards through digital tools based on the selectivity perspective

The EU funded three major research projects specifically dedicated to discards in recent years, the MINOUW, DiscardLess and iSEAS projects. The paper proposes to use those projects as case studies of how digitization can contribute to addressing discard.

Case study 1: The H2020 MINOUW Project (2015-2019)

The MINOUW project ran 17 trials, but they focused on technological improvements of fishing methods selectivity, with Use cases dedicated to improving fishing gears and hooks, trials with light technology for pots, etc. as well as survivability of unwanted catches.[60] However, a number of digitization tools were used to conduct and support the trials. Based on the assumption that "the spatial distribution of potentially unwanted catches is an important source of information to contribute to lower production of discards", the MINOUW project produced "high-resolution maps of potentially prob-

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lematic fishing areas vis-a-vis the generation of discards".[61] Existing datasets (such as MEDITS and MEDIAS in the Mediterranean or PT-IBTS in Portugal) were used to produce distribution and abundance maps of targeted species. Those maps were coupled with fishing effort distribution maps derived from remote vessel tracking data (VMS and AIS) of targeted fisheries to produce maps featuring areas likely to produce discards.[62] This provides an interesting example of how ocean modelling data (here the distribution and abundance maps) can be associated with fisheries monitoring data (derived from VMS) to produce tools supporting skippers and managers decisions. In fact, according to the MINOUW project, "the cross-analysis of density patches of potential unwanted catches and distribution of fishing effort can support the identification of spatial-temporal hot-spots in which the fishing pressure should be reduced to limit the amount of discards".[63] This in turn could be translated into policy based on spatial-based management actions, such as Fisheries Restricted Areas (FRA).[64] For instance, the project identified and mapped areas with high quantities of discarded catch or undersized catch and overlapped them with the existing FRAs and the proposed Marine Protected Areas (MPAs) explore how spatial closures could contribute to the reduction of bottom trawl discarded catch/undersized catch.[65]

To demonstrate the potential of such an approach, the MINOUWApp was developed as a web-based tool in support of by-catch and discards management.[6667] According to MINOUW, such an approach could also usefully feed into broader spatial management policies such as "functional" Maritime Spatial Planning (MSP).[68]

Besides, MINOUW also developed a dedicated Data-recording application aimed at incentivizing self-monitoring of new discard reducing measures tested in the field by fishers.[69] According to MINOUW, "the general objective of this App [was] to devise technological solutions to control and monitor compliance in the context of the Landings Obligation of the CFP. Through the use of this App, fishers [could] collect digitally relevant information from their fishing trips, including positioning information using the GPS mobile device and the obtained results [would] help increase the level of control, compliance and enforcement of rules by the fishers".[70] The App was "designed in consultation with stakeholders during the multi-actor process [...] and its use was agreed in principle by voluntary fishers in pilot case studies".[71]

However, the App faced significant barriers to adoption, and was met with a lack of uptake from fishers. This failure especially related to the timing of the App development. Reasons for failure include that national mechanisms collecting discard rates within the electronic logbook systems were also developed in the framework of national discard plans, making the App redundant. Broadly speaking, defiance against the implementation of the landing obligation also did not facilitate the uptake of the self-reporting discard App. Ultimately, the App was used in partnership with the General Fisheries Commission for the Mediterranean (GFCM) to support the collection of the by-catch/discards data needed by the organisation's mid-term strategy.

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Case Study 2: The H2020 DiscardLess project (2015-2019)

In the DiscardLess project, a dedicated work package focused on "adaptation of fishing strategies". For the nine project Cases Studies, dedicated results were available for the objective "avoiding unwanted catch", both in terms of gear technology (not considered in the present paper) and fishing strategy. Amongst the digital tools tested by DiscardLess, "fisheries independent and dependent data were gathered to create maps showing zones of high discard likelihood in space and time from the Balearic Islands".[72] Based on spatial data, graphs were also produced that "would help fishermen to choose the best season and fishing ground in order to avoid taking fish under the [Minimum Landing Size] (MLS)". During a study in the Gulf of Lions, "distribution maps of undersized commercial species were used to undertake a spatial planification exercise aiming at proposing spatial strategies to avoid discard at seasonal scale", leading to the production of "many avoidance scenarios [...] in order to identify strategic zones that need to be avoided to protect undersized commercial species".[73] Data on captures and fish distribution were coupled. According to the study results, "seasonal scenarios of spatial planification represent an interesting baseline for discussion between scientists and fishermen and then could help to elaborate management plans".[74] In the Celtic Sea, maps overlapping areas with persistent unwanted and desired catch were produced "to equip the fishing industry with information that may help inform where to best target effort".[7576] A Use case also mentioned that "some collaboration with the industry have started to develop a phone application that would allow fishermen to exchange in real time on discard hot spots".[77] However, the Use Case also reported that "spatio-temporal effort reallocation seemed to be highly constrained by regulations, weather, and abundance of marketable resource".[78]

These dynamic and spatial approaches to discards are all the more so interesting that during interviews conducted in the framework of DiscardLess, tactical approaches used by fishers in different sea basins included changing time, depth, season and place of fishing.[798081]

Case Study 3: The Life + iSEAS project (2014-2018)

The iSeas project aimsed at applying existent knowledge and innovative solutions for discards reduction and management in the fisheries sector.[82] Objectives of the project included installing a set of standardised technologies able to perform the work of qualified observers (iObserver) for automatic identification and quantification of the whole catch on board commercial vessels. The iObserver was connected to a Redbox that contextualised the information related to the Trip and the Haul, by connecting with different navigation instruments of the ship and collecting information at regular intervals about the position, heading, speed and depth.[83]

The project thereby targeted at optimising the fishing activity based on spatio-temporal data, especially defining more appropriate areas/periods/species in terms of lower discard levels through the development of decision-making tools for fishing activity optimization: Spatial Data Infrastructure (SDI) and discard probability maps.[84] Any Geographic Information Systems (GIS) software could access this data. In addition, a dedicated Geoportal was created to visualise the data through map viewers.[85] The geoportal featured two layers: "a public one with free access containing generic information and layers with the results of some static models; and a private one that, in addition to the information

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offered in the public, allows access to the fishing/ capture data (filtered according to the user access permissions. That is, each skipper has access exclusively to the catch data of his own ship), and to the dynamic models of prediction".[86] This tool could be used by skippers to identify areas with minimal risks of discards to adapt fisheries strategies in real-time as well as to plan better fishing areas. In addition, it could also be used by fisheries authorities to "determine, in real time, closures of areas where high percentage of discards of certain species are being generated or large volumes of specimens below minimum legal size are being captured, implementing more agile and effective policies".[87]

iSEAS also developed Discard Probability Maps based on statistical tools (mathematical models) aiming at the production of maps to identify and visualise the best fishing areas, considering those areas as the ones with lower discarding probability.[88] The probability maps build on a sound understanding of ecosystems functioning, deriving insights based for instance on water temperature, salinity or bathymetry. Historical databases alongside more recent catch data collected by observers or through the project by the iObserver fed the models.

For researchers in the project, the tools developed through iSEAS fed into and contributed to the broader marine spatial planning framework.[89] They called for "a better marine spatial planning approach [in] fishery management".[90] Reversely, they considered that combining the definition of area where fisheries should be avoided to preserve discard-prone species with efficient fishery management measures "represents the first step towards facilitating an effective Marine Spatial Planning".[91]

Key takeaways from the Case Studies

The three considered Case Studies clearly demonstrate that digital solutions can be used to significantly reduce bycatch and discards. The main approach used in those projects was area -based. In short, the idea was to use a Geographic Information System (GIS) to provide information to fishers on which areas they should fish or not. The data used was derived both from historical and pre-existing data sets on marine ecosystems, and real-time data collected onboard fishing vessels. The case studies show the potential of coupling data about the marine environment, such as fish distribution and abundance, but also bathymetry, currents, etc., and fisheries data, including on vessels position and catch. A great added value of those projects was to provide guidance on how to avoid discards not only from a spatial but also a temporal dimension. Fishing is a seasonal activity, and digitization can help with adopting a dynamic approach to its management.

The information produced through digitization benefited multiple stakeholders: fisheries managers, fishers, control and administrative authorities and the general public. It helps with improving the compliance with legal requirements such as the landing obligation. They also contributed to collecting more precise information about marine ecosystems, for instance by checking models against the reality of what was observed on fishing vessels. Manager, control and administrative authorities could benefit from improved knowledge of real activities at sea. User-friendly and dynamic tools such as geoportals were highlighted as contributing to more effective area-based fisheries management decisions, such as the establishment of FRA. From the fishers perspective, discards represent a waste of time, money, and space onboard due to the landing obligation. Digital tools developed allowed skippers to make better informed decisions on where and when to fish. Sharing real-time field data from

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their activities at sea also highlights the role fishers can play as ocean practitioners. Making use of available digital tools, they could strengthen the knowledge on marine ecosystems and thereby improve the management of natural resources, demonstrating they are part of the solution. This shows how a positive narrative can be built regarding the use of digital tools onboard, beyond top-down monitoring and control. In that perspective, the use of public portals displaying generic information collected about fishing activities could also contribute to reinforcing the link between fishers and consumers and citizens. Lastly, the case studies pointed out how digital tools can help integrating fisheries management in broader integrated ocean policies. A number of articles especially called for reinforced relationships between maritime spatial planning and fisheries management.

While technical solutions could be found to address technology challenges, the projects cast the light on the process and "human" dimension of developing new digital tools. For instance, although a participative approach to digital tools development is necessary, the case studies show that it might not be enough to guarantee technology uptake in case the broader legislative/policy framework does not provide sufficient incentives/clarity to fishers. A clear mapping of existing digitization initiatives is necessary, including at national/local level, to avoid redundancy. It is therefore important to consider all dimensions of the exploitation phase of projects from the very beginning.

4.3. Addressing discards from a law enforcement perspective with digital MCS tools

A number of pilot tests and studies have looked into the potential of digitization to address discards from a law enforcement perspective. Those feed into the literature usually referred to as "Remote Electronic Monitoring" (REM). In 2021, the EU Fisheries Control Coalition looked into past Electronic Monitoring (EM) programmes in European waters (EU Member States and Great Britain). Out of the 27 pilot studies and trials listed, 13 directly referred to objectives relating to discards and landing obligation.[92] Another 5 related to monitoring of bycatch, which is a key driver of discard. Addressing discards and enforcing the landing obligation are significant drivers of fisheries EM tools in Europe.

Based on a review of the 27 pilot studies and trials, the Coalition paper offered an analysis of key REM challenges and their solutions. The paper especially looked into:

- Technical challenges related to REM devices themselves, to the specificities of fishing boats (including of SSF), to the type of fisheries;
- Political challenges relating from ethical opposition to EM technology;
- Financial challenges relating to costs and access to funding

Overall, the paper demonstrated the readiness and suitability of REM technologies to implement the CFP, including the Landing Obligation. Best practices and solutions derived from those pilot studies and trials can also serve as a basis for future EM programmes.

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5. Discussion and outlook

The projects, pilot programmes and studies analysed in this paper show that new technologies offer many ways to successfully address the practice of discarding. Chiefly, they provide tools to help avoid unwanted catches in the first place. They also help monitor the implementation of policies to prevent discarding, such as the landing obligation, including thorough remote electronic monitoring.

What the number of considered studies highlights is that the challenges do not necessarily lie with issues of technological development, but rather in human ones. SSF, for example, face the issue of having limited space onboard vessels to install new monitoring devices. However, such challenges can be resolved, for instance by installing custom mounting infrastructure to resolve camera location issues. Many digital tools dedicated to resolving discarding were also developed on the basis of simple smartphone interfaces, again addressing any issues associated with the limited dimension of ships to add tools. But the case studies show that it's not all about technology, but also humans. To name a few, acceptance by and co-construction with users, proper training, access to funding for development and installation or alignment of digital solutions with policy and legislative contexts have surfaced as issues that are equally, if not more, likely to disrupt the deployment of digital technologies.

When examining strategies to prevent unwanted catches, the available literature is at least three years old. Additional progress has been made more recently in terms of broader digitisation of both marine ecosystems and maritime industries, including with greater emphasis on modelling climate change related shifts in species distribution and abundance. These newly-available data and models could constitute the next steps of such programmes. They will then both inform fisheries and policymakers on what to do now, as well as advise on how to plan future fishing activities in a sustainable manner.

Likewise, progress has also been made in terms of spatial data handling and integration, for instance in the framework of MSP. The latter has especially seen significant progress over the course of the past few years in the EU, driven by the first deadline for implementation of the MSP Directive (31 March, 2021). The most recent studies clearly indicate that fisheries have failed to be properly taken into account in the European plans made public so far. In fact, the three selectivity projects studied called for better integration of fisheries and spatial planning processes. However, these studies do not seem to have looked far beyond the harvesting perspective of fisheries, or beyond fisheries more generally. A number of papers only considered MSP as a sectorial mapping exercise. Doing so, they missed out on the many important aspects of MSP, including its iterative nature, the need for a cross-sector approach, as well as its participative and political dimensions. While the studies considered how spatial planning could feed into fisheries management, they fall short on how area- and seasonal-based fisheries management data could also feed into broader maritime spatial plans.

Further, studies examining MSP and fisheries often did not reflect on the specific European context. In the EU, the Maritime Spatial Planning Directive (2014/89/EU) sets up an ambitious framework for MSP in EU seas. The directive, adopted in 2014, was already part of the legislative framework that could have been considered by the case studies when linking fisheries management to MSP in the EU. In future fisheries projects looking into digital area-based management tools, the participation of MSP

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specialists could help improve the mutual understanding of planning and fisheries scientists. For instance, this could support digital area-based tools being developed in a fisheries context to prevent bycatch and discards or to improve fisheries management. Such tools can also be used in an MSP perspective, such as to inform planning authorities about issues such as conflicts between sectors within given areas at sea, to help guide how areas are designated by MSP for deployment of maritime activities, such as offshore renewable energy.

Since the programmes analysed were conducted, new policy frameworks have been set up or reinforced, including in the context of the EU Green Deal. Based on the principle of "making sure no one is left behind", the latter calls for all stakeholders, including fishers, to be involved in how maritime activities evolve.[93] Similarly, some issues have gained further importance, such as that of resolving conflicts between fisheries and other maritime sectors within shared sea spaces. Further, it would be worth exploring the prospects opened by newly available data and spatial approaches to improve fisheries management, including to address discarding. It would also be worth considering how the data collected for fisheries management purposes could inform broader processes, such as MSP. Utilising this to cast light on fishers' needs and realities beyond fisheries management could motivate fishers to participate in digitisation programmes. Lastly, since the considered studies were conducted, broad processes such as the United Nations Decade for Ocean Science have been launched. Fisheries data would need to be incorporated into the knowledge that is built up in such frameworks. This could also offer an interesting avenue for valuing fishers' knowledge and role in safeguarding the ocean.

A greater emphasis on how data collected on issues like discarding could feed into traceability and benefit fishers could also prove useful for other stakeholders along the seafood supply chain, authorities and consumers. Fisheries data, including records of measures to address discarding, will be highly valuable inputs into what is now called "electronic catch documentation and traceability" (eCDT), i.e., "a combination of technologies into a linked set of systems that together provide ready access to reliable information and the means to share that information securely across the globe".[94] Robust fisheries data and its availability for programmes such as these are all the more important today in the context of the EU Green Deal and its associated policies such as the Farm to Fork Strategy, as well as the upcoming Sustainable Food System Framework Initiative. In the future, sustainability will be key to access EU food systems and it is very likely that labelling will be used to guide consumers; this will require data to be collected along the whole seafood supply chain. In that regard, working as of today to facilitate the collection of seafood data can also be promoted as a way for small-scale fishers to anticipate those soon-to-be new legal, market and societal demands. In practice, preventing discards is key to fisheries sustainability and it seems very likely that the market, from consumers to actors upstream in the supply chain, will require fishers to prove that they do not engage in such activities. For instance, in France, the existing public label "Pêche Durable" requires that fishing activities do not jeopardise the populations of marine species other than the target stock, and that bycatch is both limited and well-documented.[95]

From a technological point of view, case studies offered limited information about the data architecture perspective, i.e., how data is stored, shared, protected, etc. Likewise, it does not seem that past

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pilot projects looked into interoperability of data, i.e., the capacity of multiple systems to access, exchange and process data. With a high rate of digitisation ongoing across industry in Europe and beyond, the challenge of interoperability to de-silo the data produced is already well known.[96] This is all the more relevant if the fisheries data collected is also meant to be integrated into broader frameworks, such as MSP. It would therefore be interesting for future programmes to e.g., consider the integration of spatial data into tools such as EmodNet from the beginning of data collection.

Finally, digital projects were considered from a fisheries perspective, but often not from the technology-development perspective. In MCS pilot projects, this dimension was more stringent due to issues concerning privacy, confidentiality and control of data. However, the bigger picture of the challenges related to the digital transition were not highlighted. For instance, issues such as technological sovereignty did not seem to be considered. Digital tools require maintenance, be it the data collection devices or the associated data infrastructure, and projects considered for the selectivity dimension of this paper are very informative in that perspective. However, reviewing the results of these now-completed projects sometimes proved difficult, as some websites and associated online tools were either not functioning or no longer up to date. The absence of such updates puts into question whether an application developed for a smartphone or similar device a few years ago would still be compatible with the latest operating systems. Information about how project results were used once funding ceased was also difficult to find, when available. The long-term exploitation of publicly-funded digital projects should therefore be considered before such projects are terminated.

In order to improve future fisheries digitisation projects, this paper proposes the following recommendations:

- The human dimension of developing new digital technologies, including a participative approach and a clear data governance framework, should always be considered.
- Digital solutions developed to improve fisheries sustainability should be leveraged to deliver integrated policies, such as maritime spatial planning. This requires strengthened dialogue between fisheries and planning scientists, and for fisheries data to be fully interoperable with that of other maritime sectors and planning tools. This would help ensure conflict-free marine areas for fishers, fisheries managers, maritime planners and other maritime sector stakeholders.
- Digital fisheries management tools should leverage newly-available models to offer both static and predictive information to guide fishers and authorities in the long run.
- Digital tools meant to improve the sustainability of fishing practices will most likely be increasingly embedded in the framework of sustainable food systems, for instance for labelling. Acknowledging this link and reinforcing the interoperability of fisheries data with traceability systems will be key.
- Fisheries digitisation projects should be developed in a silo basis and should consider the broader technological environment and raise issues such as data sovereignty, to better integrate fisheries and technology policies.

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- Greater attention should be paid to the long-term exploitation of digital projects to streamline uptake of the latest innovations.

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