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ZAKLJUČNA NALOGA (FINAL PROJECT PAPER)

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ZGODOVINA, SEDANJOST IN PRIHODNOST PRILOVA V EVROPSKEM MORSKEM RIBIŠTVU

(PAST, PRESENT AND FUTURE OF BYCATCH IN EUROPEAN MARINE FISHERIES)

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(Past, present and future of bycatch in European marine fisheries)

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Izvleček: Prilov predstavlja naključni ulov neciljnih vrst, vključno z ogroženimi in zaščitenimi, in ulov osebkov ciljnih vrst, ki ne ustrezajo zakonskim omejitvam. Pojavil se je z razvojem ribolovnih tehnologij, saj so le te v kratkem času izjemno napredovale. Napredek se je najbolj izrazil v povečanju ulovljenih količin rib, kar pa je imelo za posledico postopno zmanjšanje selektivnosti ribolovnih orodij. Prilov se pojavlja pri uporabi vseh ribolovnih orodij, vpliva pa na mnogo različnih vrst v morju. Še posebej izpostavljen je negativen vpliv na vrste, ki imajo v ekosistemih ključne vloge (plenilci na vrhu prehranjevalnih spletov, npr. morski psi). V zadnjih 50 letih je prilov eden od osrednjih problemov industrijskega ribolova. Odgovorne institucije ga poskušajo reševati na več načinov. Vključen je v svetovne, regionalne in nacionalne načrte upravljanja ribjih staležev. Za zmanjševanje prilova so v zakonskih aktih predpisani različni tehnični ukrepi. Kljub vsemu temu, pa se ukrepi še vedno izvajajo regionalno. Mnoge morske vrste pa v svojem življenjskem ciklu uporabljajo obširna območja in lahko prečkajo celotne oceane med prehranjevalnimi in razmnoževalnimi območji. To pomeni, da dobro upravljanje prilova v eni regiji pomeni malo ali nič, če se v sosednji regiji upravljanje ne izvaja. Namen pričujoče naloge je pregled in analiza prilova v morskem ribištvu v preteklosti in sedanjosti v morjih Evropske Unije. Naloga vključuje tudi pregled mednarodnih dogovorov, pravnih podlag in tehničnih ukrepov za zmanjševanje prilova ter njihove učinkovitosti ter se v zaključku opredeli glede mogočih scenarijev v prihodnosti.

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Abstract: Bycatch, in general terms, refers to the incidental catch of non-target species, including endangered and prohibited ones, and/or the catch of the wrong size or sex of the target species. This issue found its origin as soon as fishing technologies started to be improved in terms of catch quantity and at the same time selectivity started to decrease. Especially for the last 50 years, bycatch is one of the main problems included within all fisheries management plans worldwide, since the impacts of this incidental catch are of high concern worrying. Impacts are specially worrying when bycatch takes place upon species with important ecosystem functions and services such as the ones from marine megafauna, such as sea turtles, sharks, marine mammals and seabirds. Many management plans have been developed during the last decades in order to find it a solution, but in the great majority of cases these measures have been regional and not internationally undergone.

Therefore, what I am looking for in this work is to analyze the situation of bycatch in European waters in order to determine the direction of its situation, together with a summary of the measures and potential solutions to resolve this issue.

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ABREVIATIONS

AFMA: Australian Fisheries Management Authority.
CECAF: Fishery Committee for the Eastern Central Atlantic.
CIRVA: International Committee for the Recovery of the Vaquita.
CFP: The Common Fisheries Policy.
COFI: Committee on Fisheries.
EAF: Ecosystem Approach to Fisheries.
EBFM: Ecosystem Based Fisheries Management.
EU: European Union.
FAD: Fish Aggregating Device.
FAO: The Food and Agriculture Organization of the United Nations.
FRA: Fishery Restricted Area.
GFCM: General Fisheries Commission for the Mediterranean.
ICCAT: International Commission for the Conservation of Atlantic Tunas.
IUCN: International Union for Conservation of Nature.
LED: Light-emitting diode
MPA: Marine Protected Area.
MSDF: Multi-Country Sustainable Development Framework.
NASCO: North Atlantic Salmon Conservation Organization.
NEAFC: North East Atlantic Fisheries Commission.
NGO: Non Governmental Organization.
NOAA: National Oceanic and Atmospheric Administration.
RAC/SPA: Regional Activity Centre For Specially Protected Areas.
RFB: Regional Fishery Body.
RFMO: Regional Fisheries Management Organization.
TED: Turtle Excluder Device.
UN: United Nations.

1 INTRODUCTION

1.1 Development of marine fisheries and emergence of bycatch

Fishing in both freshwater and marine systems started as soon as modern human being (*Homo sapiens)* appeared on Earth. Isotopic evidence for Neanderthal and early modern human diets in Europe revealed a dietary shift from being carnivores to a wider diet, including the consumption of aquatic resources (Richards and Trinkaus 2009). Art representations show the fishing activity present in Egyptian and Greek civilizations from Early History (Roff and Zacharias 2011). Fishing techniques and technologies have been hugely improved along the last hundreds of years, moving from simple hooks, rods and lines, nets and harpoons to vessels towing large nets through the sea. Similarly, fishing vessels shifted from being small and only used close to the coast to being every time larger, with greater capacities for catch and able to travel longer distances (Roff and Zacharias 2011).

With the ancient tools, such as simple hooks and harpoons, early fishermen practically selected and targeted the catch, thus rarely producing any bycatch. However, fishing gears and technologies shifted from a highly selective fishing to a fishing where selectivity has decreased in such an alarming way that non-desired catch in some fisheries has reached up to 90% of the total catch (Kelleher 2005). This non-desired, incidental catch (bycatch) included undesirable size or age classes of the target species (e.g. juveniles or large females) or the incidental take of other non-target species (Lewison et al. 2004a). Therefore, the origin of bycatch issue was the moment when fishing vessels and technologies started to be rapidly developed and highly improved, showing every time lower selectivity (Norse and Crowder 2005a).

1.2 Marine fishing gears

Emergence of bycatch result from the development of modern marine fishing techniques, technologies and gear. Therefore, in order to understand bycatch, we need to understand how marine fishing gears operate.

Fishing gears can be classified in two groups: on the one hand, those towed by boats in order to persecute and catch fish and therefore called ‘active fishing gears’, such as trawls, dredges and purse seines (*Figure 1*). Those fixed into the environment and where the animals are the ones who move towards them are therefore called ‘passive fishing gears’; those include longlines, gillnets and traps/pots (*Figure 2*). In general, active fishing gears show a bigger impact into the physical environment together with the highest bycatch rates (Watling L. 2005).

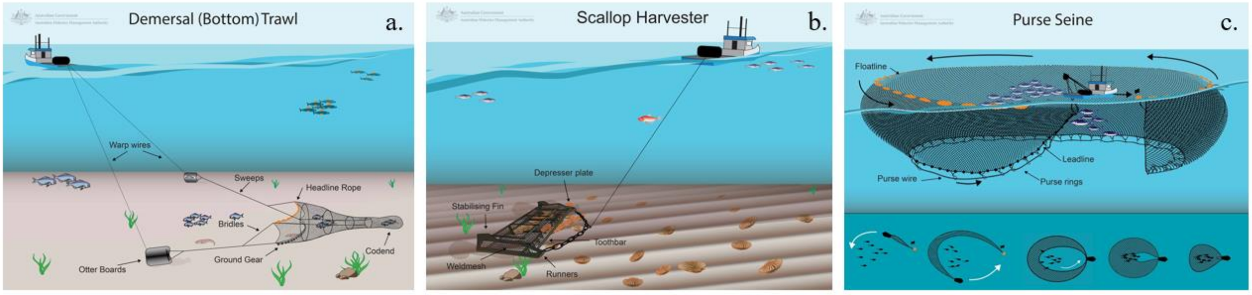

Figure 1: Active fishing gears (a - Demersal trawl, b - Seafloor dredge, c - Purse-seine).

Bottom (demersal) trawl (*Figure 1a*) is by far the fishing gear with the highest bycatch rates worldwide. Alverson et al. (1994) determined that this fishery was the responsible for more than two thirds of the total global bycatch while its total fish production was no more than the 2% of the total global one in the 1990s. Trawling net consists on the hauling of a cone-shaped net through the seafloor which contains two heavy doors or wings (otter boards) in the front of it that maintain the net open and close to the bottom. Furthermore, the bottom of the net mouth is normally made by a heavy and thick metal cable which, together with the doors, contributes to the huge sea bottom damage (Watling L. 2005, FAO 2018a).

Similarly, dredging (*Figure 1b*) consists on a net being towed throw the sea bottom differing from trawling in the presence of teeth in the base of the net mouth to dig into the sea floor and take organisms living within this, such as scallops, oysters and other clam species (Watling L. 2005, FAO 2018a). As a consequence, it fully damages the seafloor and is one of the biggest bycatch producers among all fishing gears (Jenkins et al. 2001).

Purse seine (*Figure 1c*) encircles of a school of fish by the hauling of a net through the sea surface by a boat. The bottom of the net has a wire which closes when the encirclement is completed, so the fish get trapped inside. This fishery usually targets different tuna species and uses artificial or natural fish aggregating devices (FADs) in order to attract the fish (AFMA, Heppell S.S. et al. 2005).

Longlines, as a passive gear, consist on a mainline and branch lines ending in baited hooks which can be placed up near the surface, in the middle of the water column or at the sea bottom. In the case of the pelagic longline (*Figure 2a*), its length can vary from few hundred of meters in coastal fisheries to 50 km in the open oceans and mainly focuses on big pelagic fish such as tunas, billfish and swordfish. Demersal longline (*Figure 2b*) can be many kilometers in length, present thousands of hooks and mainly target on demersal fish and some shark species. For pelagic longlines, the depth at which hooks are placed together with the distance between them and their number are the most important parameters that determine the target species. The biggest impact of longlines upon ecosystems is the high rates of bycatch of non-target finfish, sharks, sea turtles and seabirds (FAO 2018a).

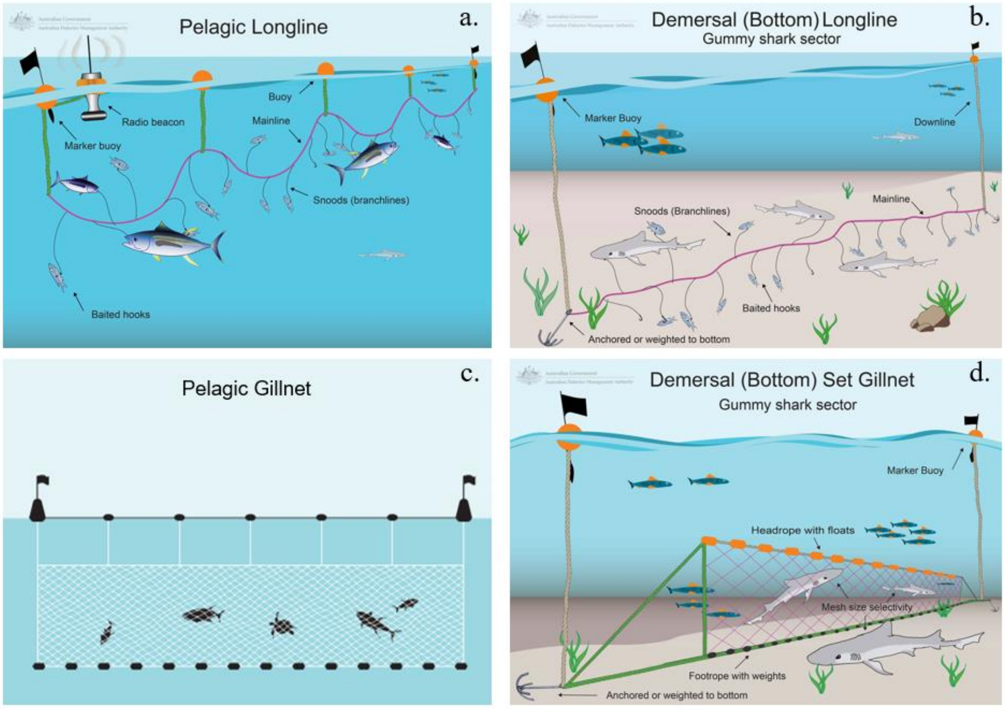

Figure 2: Passive fishing gears (a – Pelagic longline, b – Demersal longline, c – Pelagic gillnet, d – Demersal gillnet).

Gillnets are long rectangular panels of nets with diamond-shaped mesh placed vertically both in the upper part of the water column (*Figure 2c*), in the middle part of this (drift gillnets) or anchored to the sea bottom (*Figure 2d*) (FAO 2018a). They are usually placed in lines of large numbers forming the so called 'fleets' of nets but they can be also used alone. A combination of buoys and weights are the responsible for the vertical disposition of the net. Depending on the depth they are placed gillnets target different fish species. The functioning of this fishing gear is simple, based on the accidental entanglement of fish by their spines, gills and/or fins. This also results in the entanglement of non-target species such as rays, sharks, dolphins, seabirds and sea turtles. Furthermore, drift gillnets were called 'walls of death' in the past due to the high bycatch caused by these (Sneed 1991).

1.3 Marine fishery production and status of world fisheries

Both fisheries and aquaculture underwent a huge development in the last half century and global fish production increased from 19.3 million tons in 1950 to more than 160 million tons in 2014 (FAO 2011a, 2016). Within this total fish production, marine fisheries had always been the predominant contributors, responsible for the 86% of the total catch in 1950. Even after the major development of marine and freshwater aquaculture, marine fisheries contribute to the 49% of the total fish production by 2009. Within this period, marine fisheries suffered several development stages with several high peaks of the total catch.

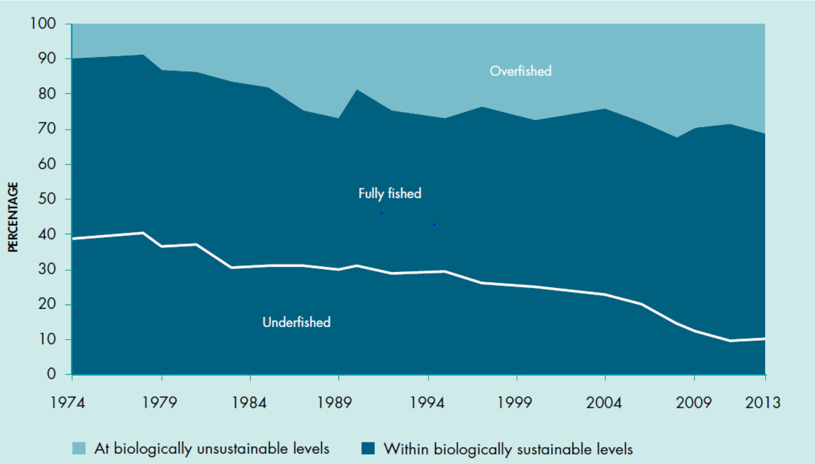

Figure 3: Global trends in the state of marine fish stocks for the period 1974-2013 (FAO 2016).

Marine fisheries production reached its ever-maximum peak of 87.7 million tons in 1996 and after this it showed a gradual decrease, while marine and freshwater aquaculture and inland fisheries productivity kept increasing (FAO 2011a).

Based upon data from the Fishery Statistical Collection (FAO 2018b), it is possible to analyze the global shift on the exploitation status of different fish stocks through time (*Figure 3*). The analyzes showed a continuous increase of the proportion of overexploited and fully-exploited stocks, with a decrease of the non-exploited ones in the period from 1974 till 2013 (FAO 2016). The percentage of overfished stocks increased from a 10% in 1974 to a 26% in 1989. After 1990 this percentage kept increasing in a slower rate till achieving a level of around 30% by 2009. Similarly, the percentage of fully exploited stocks also increased from a 50% in 1974 to a 57.4% in 2009, while the percentage of non-fully exploited stocks decreased from a 40% in 1974 to a 12.7% in 2009**.** Total marine catch has showed a gradual decrease through decades (*Figure 4*), which combined with the data from the changes on stock status results in the fact that oceans are getting emptier every time (Norse and Crowder 2005a).

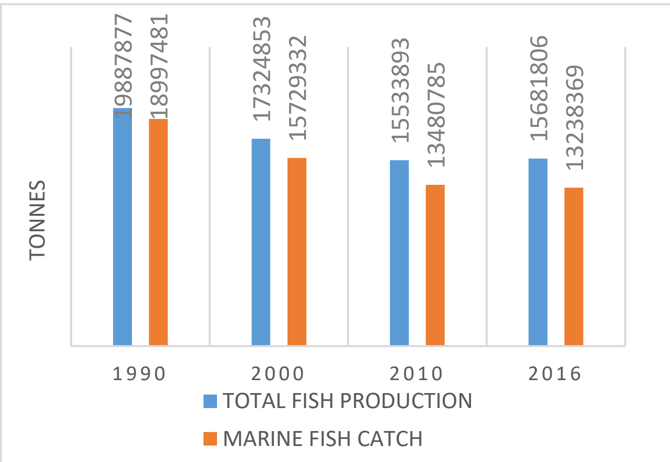

Figure 4: Marine fish catch in relation to the total fish production for Europe in the 1990-2016 period (FAO Fishery Statistical Collection 2018).

2 MARINE FISHERIES BYCATCH

2.1 Bycatch definition

Different definitions have been given to bycatch through the years. Alverson et al. (1994) describe it as the combination of the incidental catch and the discarded catch. The incidental catch consists of the retained catch of non-targeted species, while the discarded catch is the part of the catch returned to the sea due to personal, economic or legal consideration. Thus, discard is itself considered as a subset of the existing bycatch and individuals belonging to this category could be released unharmed, partially or highly injured and/or dead (Alverson et al. 1994).

FAO (2011b) declares that species and sizes considered as bycatch should be designated by the fishery management plan. When not designated, bycatch is the part of the catch not following the fishery management plan. Here, bycatch is also considered as the prohibited catch of a fishery, and in the case of multispecies/multi-gear fisheries such as trawling where selectivity is very low, bycatch refers to the catch of certain species which shouldn't have been caught due to the ecological and economic consequences.

Lewison et al. (2004a) gave probably the most accepted definition of bycatch. The authors described it as the incidental take of undesirable size or age classes of the target species (e.g. juveniles or large females) or the incidental take of other non-target species (Lewison et al. 2004a). Davies et al. (2009) considered it as the part of the catch that is either unused or unmanaged.

Such different definitions of bycatch hinder the analysis of its evolution through years, resulting in the incapacity of following the real situation of the issue. Together with the changes of bycatch definition the 'target species' term has also changed with the development of multispecies fisheries. This resulted that the part of the catch considered non-targeted (bycatch) in the past is today considered as part of the catch. Murawski reviewed this shift and concluded that "yesterday's bycatch may be tomorrow's target catch" (Murawski 1992).

On top of that, all these changes in the definition of bycatch through time have been the ones causing a big number of irregularities on its management and conflicts between fishing fleets and fisheries managers. In any case, what really threatens oceans and marine biological resources is not the lack of a bycatch definition, but the consequences of bycatch. Impacts of high bycatch rates are still not well known, but recent knowledge bolsters these to be detrimental and of serious concern for all biological levels, from species to ecosystem level.

2.2 Bycatch: state of the art

The issue of bycatch caught the attention of scientists and public due to a few highly visible cases involving charismatic species such as dolphins, sea turtles and seabirds. The massive incidental catch and killing of thousands of dolphins in the 1960s known as 'The tuna-dolphin conflict in the Eastern Tropical Pacific' rapidly caught public's attention. Till the 1950s, tunas were caught one by one by the pole-and-line method. In the following years, this type of fishery was largely replaced by the purse-seine fishery. The problem appeared in those vessels detecting tuna schools associated with dolphins ("dolphin sets") where the number of killed dolphins was estimated at hundreds of thousands per year during the mid-1960s (Hall 1998; NOAA Fisheries 2016). As consequence, huge declines of dolphin populations appeared by the early 1970s while dolphin stocks became depleted in 1990s (Hall et al., 2000). Bycatch problematic gained attention among scientific community, and its quantification and reduction became a major element of the in development sustainable fisheries (Lewison et al. 2004a).

Global overview

After bycatch issue was publicized, the Food and Agriculture Organization of the United Nations (FAO) published 'A global assessment of fisheries bycatch and discards' (Alverson et al. 1994). This assessment provided direct relationship between fishing gear types and consequent bycatch. Results showed that trawling was the most common fishing gear appearing in the whole collection of records, principally showing weight-based data (*Figure 5*). This was followed by nets, lines and other fishing gears. Weight-based data represented the amount of kilograms of bycatch produced per each kilogram of landed catch, while number-based data showed the number of bycatch individuals per target landed individual (*Table 1*).

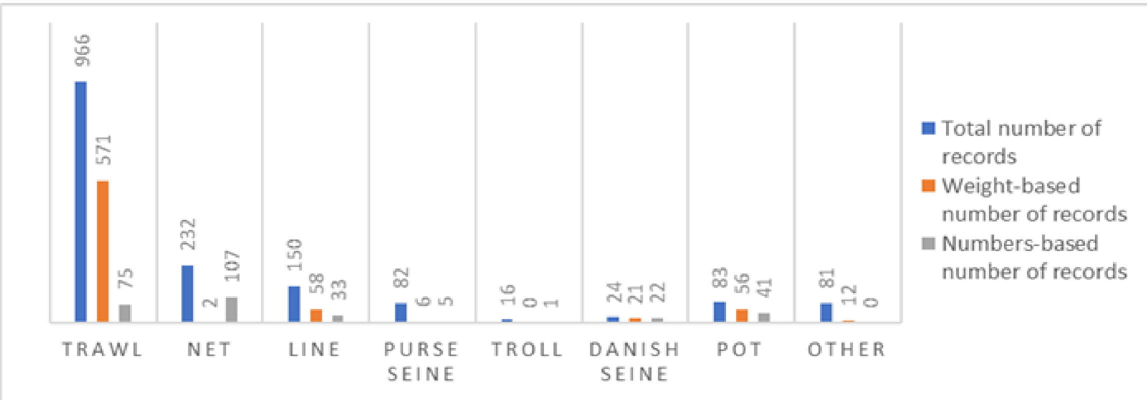

Figure 5: Bycatch-producer fishing gears and the different data type taken from them (Alverson et al. 1994).

Table 1: Main responsible fisheries for the almost 3,7 million metric tons generated bycatch for the 1990s together with their respective bycatch rates, both weight- and number-based (Alverson et al. 1994).

Fishery description	Number-based bycatch rate (bycatch number/landed catch number)
Northeast Atlantic Whiting Trawl	2.83
Northeast Atlantic Haddock Trawl	1.94
Northeast Atlantic Nephrops Trawl	1.7
Northeast Atlantic Hake Trawl	1.18
Northeast Atlantic Cod Trawl	0.51
Northeast Atlantic Plaice Trawl	0.42
Northeast Atlantic Cod Danish Seine	0.79
Northeast Atlantic Haddock Danish Seine	0.7
Northeast Atlantic Whiting Danish Seine	0.64
Fishery description	**Weight-based bycatch rate (kg bycatch/kg landed catch)**
Baltic Sea Dab Trawl	2.01
Irish Sea Nephrops Trawl	1.95
Baltic Sea Flounder Trawl	1.6
North Sea Shrimp Trawl	1.44
North Sea Whiting Trawl	1.34
Mediterranean and Black Seas Finfish Trawl	0.85
Northeast Atlantic Haddock Danish Seine	0.5
Northeast Atlantic Whiting Danish Seine	0.45
Northeast Atlantic Cod Danish Seine	0.36
Mediterranean and Black Seas Tuna Longline	0.1
Mediterranean and Black Seas Hake Trawl	0.04
Mediterranean and Black Seas Sardine Purse Seine	0.03
Mediterranean and Black Seas Flatfish Trawl	0.03

Almost 75% of all bycatch data belonged to fisheries from the Northeast Pacific and Northeast and Northwest Atlantic, with ≈30% of bycatch records referring with shrimp and groundfish fisheries (*Table 1*). The estimated global discards showed an annual average of 27 million metric tons out of 77 million metric tons of total catch for the period 1988-1990,

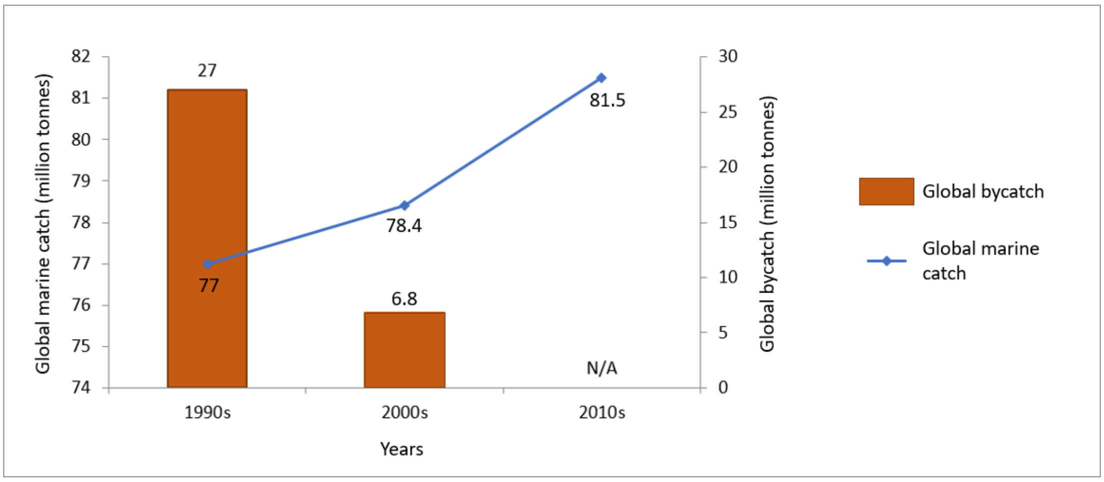

Figure 6: Global marine catch and bycatch trend in different time periods (data for the 1990s taken from Alverson et al. (1994), data for the 2000s taken from Kelleher (2005) and data for the 2010s taken from FAO (2016)).

with minimum and maximum estimation values of 17.9 and 39.5 million metric tons (*Figure 6*). Wasted resources corresponded to an average 35% of the total catch, with a possible maximum value of 51.3% (Alverson et al. 1994). It should be noted that those values lacked the information about bycatch produced in freshwater fisheries, marine mollusk fisheries and recreational fishing. Alverson et al. (1994) conservatively estimated marine mammal bycatch at several hundreds of thousands per year. These occurring in almost all fisheries, especially in driftnets/gillnets and tuna seine fisheries. Furthermore, they also estimated the global incidental take of around 40,000 sea turtles per year, with a 42% of mortality rate.

Kelleher (2005) analyzed discards from the 2000s which he defined as “the portion of the total animal organic material catch which was thrown back to the sea, dead or alive”. In comparison with previous discard estimates of 27 million tonnes (Alverson et al. 1994) results from Kelleher (2005) shifted this value to 6.8 million tonnes of dicards out of a total landing of 78.4 million tonnes (8.6%; *Figure 6*). Shrimp and demersal finfish fisheries were still responsible for the highest discard rates accounting for more than 50% of the total global discards, while their landings constituted the 22% of the total (Kelleher 2005; *Table 2*). The biggest quantities of discards were generated in the Northwest Pacific and Northeast Atlantic, accounting for the 40% of the globally produced discards (Kelleher 2005). Lewison et al. (2004b) estimated a minimum global bycatch of 250,000 loggerheads (*Caretta caretta*) and 60,000 leatherbacks (*Dermochelys coriacea*) in 2000 only by longline fisheries.

Table 2: Most relevant fisheries responsible for the production of the 7.3 million tonnes of discards ('Western waters' refers to West of Ireland and Scotland; Kelleher 2005).

Location	Fishery description	Discard rate	Other information
Atlantic and Mediterranean	Targeting tuna, bonito and billfish	16%	Highest discard rates for this type of fishery
North Sea	Netherlands beam trawl targeting sole (*Solea solea*)	--	39.1% of the total North Sea discards (average of 690,000 tonnes)
North Sea	--	--	Haddock (*M. aeglefinus*) discards = 20-50% of the total catch of the species
North Sea	--	--	Whiting (*M. merlangus*) discards = 7.4% of the mean total
North Sea	Flatfish beam trawl	70%	--
North Sea	*Crangon* and *Nephrops* beam trawl	Up to 83%	--
Atlantic	Algarve *Nephrops* and deepwater shrimp (*Crangon*) trawl	70%	--
Atlantic	Algarve demersal finfish trawl targeting hake (*M. merluccius*), seabream (*Pagellus bogaraveo*) and other species	62%	--
Atlantic	Irish razor shell (*Siliqua sp.*) dredge	60%	--
Atlantic	French Bay of Biscay hake (*M. merluccius*) trawl	56%	--
'Western waters'	*Nephrops* fisheries	60% weight-based and 80% number-based	Discards = whiting (*M. merlangus)*
'Western waters'	Irish hake (*M. merluccius*) trawl	30%	Discards = damaged target species
'Western waters'	Spanish demersal trawl	High discards of pelagic species	Due to low market demand and quota limits
'Western waters'	Irish, French or Spanish deep-water trawl targeting grenadier (*Nezumia sp.*), blue ling (*Molva dypterygia*) and orange roughy (*Hoplostethus atlanticus*)	Between 30% and 90%	Discards = blue shark (*Prionace glauca*) and grenadier (*Nezumia sp.*)
'Western waters'	Inshore bivalve dredge targeting scallop (Fam. *Pectinidae*) and razor (*Siliqua sp.*)	Between 25% and 60%	--
Atlantic	Spanish multispecies trawl	45%	--
Atlantic	Spanish gillnet, hake longline and small pelagic purse-seine fisheries	13-15%	--
Atlantic	Tagus estuary (Portugal) beam trawl targeting sole (*S. solea*) and *Crangon*	90%	--
Atlantic	*Nephrops* and deepwater shrimp fishery from Algarve	43-70%	--
Mediterranean and Black Sea	Trawling fisheries	Average 45-50%	Not many trawling grounds (good factor)

Even if not comparable due to the incompatibility of the data, the apparent reduction of global bycatch from 27 million tonnes in the 1990s to 6.8 million tonnes in the 2000s was to a large extent consequence of several different factors. First, many species previously considered bycatch started to be caught as target catch due to the development of new markets. This included the catch of smaller sizes of the same species to later produce value-added products and the utilization of low-value bycatch in aquaculture and animal feed. Secondly, a more responsible fishing activity based on regulation measures, more selective fishing techniques and effort diminution due to a major awareness and concern about bycatch issue.

When assessing global bycatch, several studies focus on bycatch rates of large marine vertebrates. This marine megafauna plays important ecological roles and have showed many significant population declines primarily as a result of fisheries interactions. The International Union for Conservation of Nature (IUCN) Red List has worked on assessing the status of many of these species populations for the last 50 years. This classified 22 species of albatross as threatened by 2010 and currently classifies six out of the seven extant sea turtle species as threatened, being incidental catch their major threat (Anderson et al. 2011; IUCN 2018). Nevertheless, huge gaps of many of these species populations status are present, especially among elasmobranchs (Oliver et al. 2015). It is not the intensity of fishing pressure what fully determines its impact on a species, but the ability of the species to overcome this (Fernandes et al. 2017). This is why marine megafauna is highly vulnerable to fishing, both to target and bycatch, due to its life history traits. These include slow growth, late sexual maturity, low recruitment rates due to low reproductive output and low sub-adult and adult natural mortality (Lewison et al. 2004a). This species are often key stone species showing important ecological functions and are therefore necessary for the ecosystem health (Fernandes et al. 2017). They are often top predators and strong interactive species, showing not only regulation of other species populations via predation but also regulation of behaviour due to the so-called 'fear ecology' (Clinchy et al. 2013). Furthermore, these are usually charismatic species and thus umbrella-species, which causes that their protection leads to the protection of many other species and the marine realm (Zacharias and Roff 2001).

Lewison et al. (2014) reviewed global bycatch data for sea turtles, seabirds and marine mammals for the 1990-2008 period in order to determine bycatch hotspots. Results showed that bycatch of the same species showed variable rates depending both on fishing gears and geographical area. The study showed that sea turtles were the most bycatch-affected species and gillnets were the highest bycatch producers worldwide, followed by longlines and trawls. Results emphasized that bycatch intensity should not be measured as individual parameters for the different fishing gears and species affected, but it should be measured in

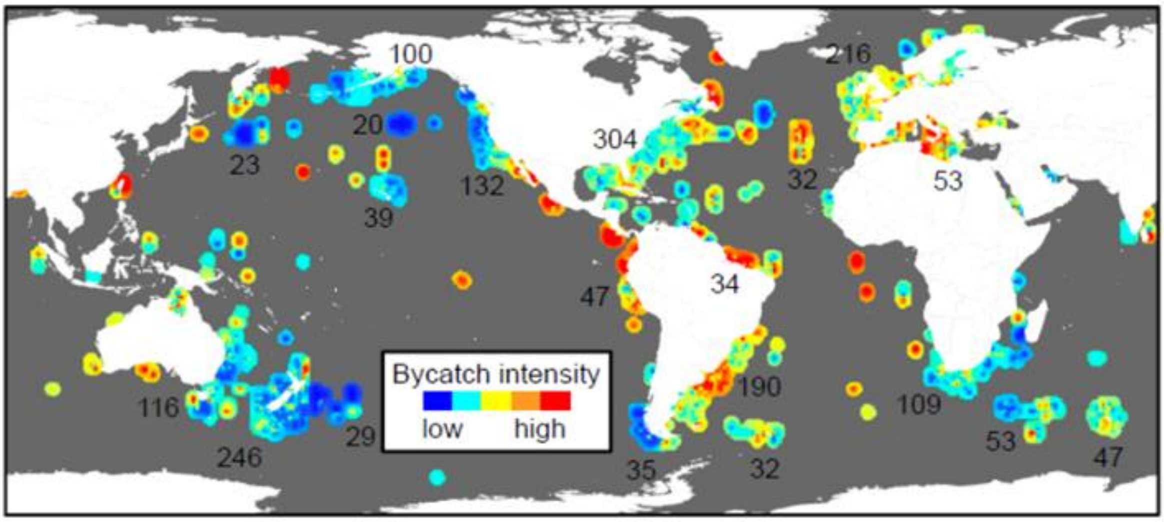

Figure 7: Worlwide cumulative bycatch intensity (Lewison et al. 2014).

a cumulative way depending on the areas. Based on this, Lewison et al. (2014) assessed the worldwide situation of bycatch in terms of cumulative impacts (*Figure 7*), where Mediterranean Sea and North European waters showed some of the highest bycatch intensities.

Due to the lack of standard metrics the authors called for standardization of methodology in order for making bycatch comparisons and analysis possible (Lewison et al. 2014). Furthermore, the authors asked for an increase on measures regarding bycatch in coastal areas and small fisheries, since all the effort was being directed to the large-scale fisheries (Lewison et al. 2014). Global elasmobranch bycatch was reviewed by Oliver et al. (2015), determining that almost 50% of the global shark production was composed by by-caught individuals in high seas pelagic longline fisheries. Ninetyfour percentage of sharks taken for fin-trade were caught as bycatch (Oliver et al. 2015). Anderson et al. (2011) estimated that in average 160,000 seabirds were killed globally every year only by longline fisheries with an upper estimate of 320,000 individuals.

Bycatch in European waters

European waters suppose a big and heterogeneus area shared by many countries and different levels of economic development, political structure, culture and religions. Those differences reflect to the management and status of fish stocks. Analysis of the stock status showed the presence of a significant geographical discrepancy through European waters (Fernandes et al. 2017). North-east Atlantic waters presented an improvement of stock status with twice as many sustainable stocks as overfished, while the Mediterranean showed a much higher portion of overexploited status. The high rates of overexploited stocks present in the Mediterranean may be result of the wrong use of the effort control, which is the management tool used in this area (Fernandes et al. 2017). Furthermore, the Mediterranean is also shared with African countries and different fleets, which results in higher fishing pressures. These factors make it difficult to have a standardized control of bycatch through all European waters.

EU waters include waters in the Mediterranean Sea, the Baltic Sea, the Black Sea and the North-east Atlantic Ocean, including waters surrounding the Azores, Madeira and the Canary Islands (Directive 2008/56/EC 2008).

In the 1990s, Northeast Atlantic fisheries were the second globally highest bycatch producers in terms of weight, with a total bycatch of 3,671,346 metric tons, the 13.6% of the global bycatch. The main bycatch components were haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), cod (*Gadus morhua*), pout (*Trisopterus esmarkii*), plaice (*Pleuronectes platessa*), Capelin (*Mallotus villosus*) and other flatfish. These resulted mainly from the large whitefish fisheries targeting cod, whiting, pout and Alaskan pollock and several trawling fisheries targeting sea dab, *Nephrops*, whiting and haddock (*Table* 1). Noteworthy here was that bycatch of cod, haddock and hake happening in the Northeast Atlantic supposed the 52% of the total global bycatch for those species. Mediterranean and Black Sea fisheries showed a total bycatch weight of 564,613 metric tons, 2.1% of the global (Alverson et al. 1994).

In the 2000s discards produced in the Northern waters were reduced to a 3.9% of the global bycatch (Kelleher 2005). This was in large extent due to the 'no discards' policy establishment in some of the countries from the area and the low diversity level of the catch. Annual North Sea discards were estimated to be between 500,000 and 880,000 tonnes, with the mean of 690,000 tonnes. For the rest of the European Atlantic waters, the higher levels of discards present were product of the greater species diversity and the dominance of demersal trawl gear of the important *Crangon*, *Nephrops* and flatfish fisheries (Kelleher 2005). Furthermore, the increasing pressure applied by several European fleets (Irish, Spanish, United Kingdom and French) caused the reduction in average size of many target species and therefore an increase in discards. In case of the Mediterranean and Black Sea discard rate was estimated of 24% of the total catch (Kelleher 2005). Almost no information about discards was available for North African countries, even though significant levels of discards could be occurring in the shrimp trawl fishery of the Gulf of Gabes (Kelleher 2005). Lewison et al. (2004b) determined that Mediterranean and Atlantic sea turtle bycatch rates were higher than in the Pacific.

Bycatch and discards of European waters show a relatively high number of information assessments on large marine vertebrates, which are available for different species, areas and

Table 3: Available bycatch rates for marine mammals, sea turtles and seabirds in European waters (N/A: data non available).

Taxa/Species	Area	Period	Bycatch rate (nº of bycatch individuals/Year)	Reference
Marine mammals				
Common dolphin (*Delphinus delphis*)	Celtic Sea	2005-2006	1,059	ICES Advice 2008, Book 1
Common dolphin (*D. delphis*)	Norwegian coastal waters	2010	1,000	Hammond et al. (2013)
Porpoises	Norwegian coastal waters	2010	6,900	Hammond et al. (2013)
Harbour porpoises (*Phocoena phocoena*)	Central and Southern North Sea	Early 1990s	6,000-7,000	Vinther and Larsen (2004)
Harbour porpoises (*P. phocoena*)	Celtic Sea	Early 1990s	2,200	Tregenza et al. (1997)
Harbour porpoises (*P. phocoena*)	Celtic Sea	2005-2006	1,549	ICES Advice 2008, Book 1
Sea turtles				
Loggerheads (*Caretta caretta*)	Mediterranean	N/A	60,000-80,000	Lewison et al. (2004b)
Loggerheads (*C. caretta*), green turtles (*Chelonia mydas*) and leatherbacks (*Dermochelys coriacea*)	Mediterranean	N/A	132,000 (<44,000 deaths)	Casale (2011)
Seabirds				
	Gran Sol, North-east Atlantic	1986-2009	56,000	Anderson et al. (2011)
7 different species	Columbretes islands in the Mediterranean	1998-1999	656-2,829	Belda and Sánchez (2001)

Seas (*Table 3*). In terms of marine mammals, yearly bycatch rates ranged from 7,000 harbour porpoises accidentally taken in the Central and Southern North Sea in the early 1990s , to

1,000 common dolphins accidentally taken in Norwegian coastal waters in 2010 (Vinther and Larsen 2004; Hammond et al. 2013). For marine sea turtles, bycatch rates estimated the take of around 132,000 sea turtles in the Mediterranean , with almost 44,000 deaths (Casale 2011). For seabirds, bycatch rates vary from 56,000 the Atlantic to almost 3,000 in the Mediterranean for different individual fisheries (Anderson et al. 2011; Belda and Sánchez 2001).

2.3 Bycatch: data reliability and data gaps

Bycatch assessment over the large areas of seas and oceanic basins used by different fisheries requires reliable and comparable time-series data. The lack of internationally accepted methodology coupled with the definition of bycatch itself resulted in many different and often hardly comparable data sets with a different level of data quality.

For example, Anderson et al. (2011) classified data used in his ‘Global seabird bycatch in longline fisheries’ study in different reliability levels. The dependent variables affecting these levels were the period of time the data belonged to and its accuracy, the last one being measured by the observer coverage (proportion of hooks monitored relative to the fishing effort or proportion of monitored vessels). Bycatch data reliability was considered ‘poor’ for the 1986-1994 period and with observer coverage less than 5%. Bycatch data reliability was considered as ‘medium’ for the 1995-1999 period and when the observer coverage was between the 5% and 20%. Bycatch data reliability was considered as ‘good’ for the 2000-2009 period and when the observer coverage was higher than 20%.

Likewise, studies on the European tuna purse-seine fisheries in the Atlantic Ocean (Gaertner et al. 2002; Amandè et al. 2010, 2011; Gondra et al. 2017) showed that the percentage of observer coverage increased gradually through the years. This shifted from a 2.9% in the 2003-2007 period to a 50-60% in the 2010-2016 period. Furthermore, a two months period every year showed a 100% coverage due to a moratorium on fishing since 2012. This gradual increase in the observer coverage was a clear effect of the increasing knowledge of bycatch and consequent establishment of new bycatch control measures. This observer coverage increase could also be the reason of the constant increase in the numbers of bycatch in the 2000-2010 period, when more accurate information was being taken. Later decrease of bycatch numbers from 2010 in advance could be the result of the implementation of bycatch control and reduction measures.

Therefore, bycatch data collection should be based on the best scientific methods available applying standard procedures in order to produce comparable data between different countries and marine basins (Directive 2008/56/EC 2008; FAO 1995, 2011b). The use of observers, standardized logbooks and vessel position monitoring systems are well known ways to collect bycatch data (FAO 2011b).

Most of the studies on bycatch were focused on large-scale commercial fisheries, which fishing effort and catch are much easier to monitor. This leaves small-scale and coastal fishery unmonitored with many few information on bycatch (Anderson et al. 2011, Lewison et al. 2014). This can show big consequences since many coastal and small-scale fisheries possibly present substantial bycatch rates and thus suppose a much greater challenge for marine megafauna than previously thought (Lewison et al. 2014, Oliver et al. 2015).

Furthermore, lack of international cooperation presents another issue in bycatch assessment. Often, bycatch estimates from large marine regions are based upon extrapolation of data obtained in studies from smaller areas. This can lead to highly biased results, often resulting in underestimate or overestimate of the real numbers.

Another problem in assessing bycatch and its impacts is caused by the biology of the affected species. In case of highly migratory species one stock can be affected by fisheries operating in different areas. Therefore, again, international cooperation in bycatch studies and bycatch reduction is crucial for obtaining reliable data that can be used for conservation purposes.

Small particularly benthic species lack the attention they deserve. Bottom dwelling fisheries such as trawling and dredging end up killing a large amount of sessile and mobile invertebrates such as corals, sponges and echinoderms. This part of the impact is rarely seen on the aboard bycatch since most of the damage to large benthic invertebrates remains unobserved on the sea bed (Jenkins et al. 2001).

2.4 Impacts of bycatch in marine systems

Bycatch takes place in all fishing fleets and in consequence affects a great variety of species. Not only charismatic species such as large marine vertebrates but other apparently “irrelevant” species such as invertebrates and finfish are under its impact too.

Its impacts can be simply classified into direct and indirect and into bycatch of target or non-target species. Direct mortality of the unwanted catch is a clear effect of bycatch, resulting in population reductions and, in the most extreme cases, leading to species extinction (D’Agrosa et al. 2000). The resulting changes project throughout the entire marine ecosystems causing numerous indirect effects which include shifts in ecosystem structure and functions.

Direct impacts

Bycatch of the target species includes the catch of unwanted size and/or sex class individuals (e.g. juveniles and pregnant females). In these cases, the size-selected harvesting already shows great impacts at species level, resulting into life history trait changes such as changes in body size, maturation and growth rates due to genetic changes (Van Wijk et al. 2013). Bycatch will cause further population decreases due to the elimination of non-mature individuals, or in the contrary, pregnant females. This bycatch leads to problems related with growth and recruitment of the populations, contributing to the unsustainability of many fisheries.

Bycatch of non-target species is the most disturbing fraction. When the species affected show similar life history traits to those of the target ones, normally r strategists, their populations may not suffer big changes and impacts and may recover more rapidly. This will depend on the intensity level and the added fishing mortality (FAO 2018a).

However, in case of species with “slow” life history (K strategists), such as marine megafauna, the impact of bycatch may be detrimental. Because of this, the catch of a few individuals belonging to certain age classes may later show huge consequences in ecosystems (Lewison et al. 2004a). Impacts of bycatch of marine megafauna start at population level, causing drastic drops on populations. Population reductions can be so severe that drive a species to extinction, both locally and globally, such as the case of the Vaquita (*Phocoena sinus*). This is the most endangered marine cetacean in the world, whose biggest and mainly threat is bycatch caused by entanglement on gillnets (D’Agrosa et al. 2000). Bycatch of the Vaquita on the gillnet fishery targeting an endemic species of finfish was one of the first threats to the species in the 1980s and 1990s. Fishing practice changed and new fisheries with smaller-mesh gillnets appeared, supposing an even bigger threat to the Vaquita (D'Agrosa et al 2000). Estimations show the fast decreasing trend of the Vaquita population through years. This was composed of 567 individuals in 1997, shifting into 200 in 2012 and decreasing even more to 100 by 2014. Most recent estimations in 2017 determined the presence of only 30 individuals (D’Agrosa et al., 2000; CIRVA 2014). Similarly, Ferretti et al. (2008, 2013) analysed the huge elasmobranch catch decrease (>94%) and disappearance of 11 species in a period from 1948 to 2005 in the Adriatic, without considering that large pelagic shark populations were already depleted by 1948.

Indirect impacts

Population depletions might result in several consequences when the species affected belongs to the highest trophic levels of the food chain. Trophic cascades are result of the disappearance of top predators and their applied top-down control on the food-web (Ferretti et al. 2008). These address the whole amount of changes in the community structure.

Changes in species interactions and energy flow along the trophic web (biotic interactions) may also appear (Lewison et al. 2014). The decrease in numbers of top predators may also cause 'meso-predator releases'. These are the increase in abundance of medium trophic level species due to the decreased competition or predation received from top predators. For instance, large sharks prey upon smaller elasmobranchs such as medium sized sharks or rays, this way, when large shark populations decline, these lower trophic level elasmobranchs show an increase in numbers of their populations (Ferretti et al. 2013). All these changes of the ecosystem structure can also include changes in species composition, which sometimes lead to the appearance of invasive species (Lewison et al. 2014). Example of this was the significant change in the Rajidae community composition which took place in the North Sea from 1950s to 1990s (Walker and Hislop 1998).

Impacts also include changes on important ecosystem functions and processes such as nutrient cycling (Lewison et al. 2014). This is the case of sea turtles such as the loggerhead sea turtle (*Caretta caretta*), which seems to have a big importance in the ecosystem well-functioning due to its role as bioturbator. The Northern Adriatic is one of the most important areas for loggerhead sea turtle's neritic foraging behaviour and as overwintering area in the Mediterranean (Casale et al. 2004). Here, loggerheads forage mainly upon mollusks by digging shallow inside the sediment (sand, mud or a mix of both) with their beaks and even flippers in the so-called 'infaunal mining behaviour' (Preen 1996). Consequence of this behaviour is the mixing of the sediment and release of nutrients into the water column, influencing the nutrient transport through the ecosystem the same way other large vertebrates do (grey whales, walruses and bottlenose dolphins). Moreover, when feeding upon mollusks loggerheads grind up big shells into smaller pieces which are later spat out both via oral cavity or in the form of feces. This results in an increase on the surface area of shell and thus higher disintegration rate and in a bigger availability of support surfaces for burrowing fauna. Thus, loggerheads are key elements of the ecosystems they're found in, especially in Northern Adriatic, where several thousands of them are being taken as bycatch in trawling fisheries (Lazar et al. 2010).

Furthermore, active fishing gears such as bottom trawls and dredges cause serious and long-lasting damage to the seafloor. These don't only affect biogenic composition like corals, sponges, oyster reefs and seagrass beds but they also have an impact on geological structures such as boulder fields and seamounts (Norse and Crowder 2005b). Trawling gear is capable to penetrate up to 6cm into the bottom sediment, and part of its equipment, the otter boards, is able to dig into even 0.3m depth. Result of this are the damage to deep-water corals like *Lophelia pertusa* and *Madrepora oculata* in Norwegian and West Ireland continental shelf break waters and the damage to *Posidonia oceanica* beds in the Mediterranean (Fosså et al. 2002, Hall-Spencer et al. 2002, González-Correa et al. 2005). Both seagrass beds and coral reefs are proved to be biodiversity hotspots for all kind of fauna and this function seems to disappear when fishermen decide to clear the area before the start of fishing activity (Fosså et al. 2002). Apparently, this aspect may be the least considered one but with sufficient consequences since it affects the whole ecosystem, both biotic and abiotic components. Other gears, such as pot fishery, show relatively low bycatch rates but they show an impact on physical environment due to the direct contact with corals, bryozoans, sponges and similar benthic organisms (Öndes et al. 2017).

3 BYCATCH: SOLUTIONS

3.1 Policy intruments

Bycatch issue is such of major concern at the moment that bycatch management is now synonym of fisheries management.

Management of fisheries shows different levels depending on the jurisdiction, going from international, to regional and to national. Recognising the fact that many fish stocks go further than the areas on national jurisdiction, different Regional Fishery Bodies (RFBs) were developed by groups of States or organizations in order to promote the long-term sustainability of fisheries where international cooperation was needed for management of stocks. When RFBs show legal ability to adopt compulsory conservation and management measures to their members and have action at least partially in the high seas these start to be considered as Regional Fisheries Management Organizations (RFMOs).

The the Food and Agriculture Organization of the United Nations (FAO) is a specialized agency whose main objective is defeating hunger in the world. For this, its Fisheries and Aquaculture Department outlined the important role of aquatic living resources on the well-being of the poor and less developed countries. It promotes and collaborates in the development of proper management and control measures, plans and actions with the final purpose of carrying out a responsible and sustainable use of these resources and the environment they are found in. The Committee on Fisheries (COFI) is the principal FAO authority for fisheries. This is a subsidiary body established in 1965 which constitutes the only global inter-governmental conference where major international fisheries and aquaculture problems and issues are analysed. It gives advice to governments, regional fishery bodies, NGOs, fish-workers, FAO and international community on a periodically and world-wide basis. This body's two main functions are the review of FAO's work programs and their implementation on fisheries and aquaculture, and the periodic address of the possible appearing issues and solutions.

The Code of Conduct for Responsible Fisheries (FAO 1995) is probably one of the first FAO manuscripts including bycatch-related measures within it. This resulted from the too rapid and uncontrolled growth of fisheries and its main function was to establish principles and model measures to be followed by fisheries so a proper conservation, management and sustainable use of marine resources could be achieved. it established some principles for a responsible fishing activity and the development of national policies, together with encouraging collaboration between States and further development of fishing technologies.
Mainly, the Code called for:

- Not only the conservation and management of target species, but also of other species related to these or to the same ecosystems in order to minimize wastes and bycatch (*Article 6*).

- The use of selective and environmentally friendly fishing gears (*Article 6*).

- The reduction of impact upon non-target species (*Article 7*).

- The assessment of bycatch impacts (*Article 7*).

- The establishment of measures regarding the catch of undesired species and sizes, as well as the catch of endangered species (*Article 7*).

- The implementation of new technologies and operational methods that reduce bycatch and increase survival rates of discards, such as more selective, environmentally safe and cost-effective fishing gears or technique modifications (*Article 8*).

- The development of fishing gears and procedures with the highest selectivity levels as possible, together with the establishment of observer programs and inspection schemes (*Article 8*).

- The collection of accurate and reliable data regarding total catch, bycatch and discards (*Article 12*).

The later published 'International Guidelines for Bycatch Management and Reduction of Discards' (FAO 2011b) were the result of the failed attempts to reduce bycatch and discards through years. Their main function was to promote responsible fisheries by reducing the catch and mortality of non-targeted species and sizes which were not going to be used as indicated in the Code.

However, the both afore mentioned are part of a wider policy instrument, 'The ecosystem approach to fisheries' (Garcia et al. 2003). This was result of an increasing recognition of the far-reaching environmental and social consequences of fisheries, which lead to a new approach to fish stocks management and the need to integrate it with marine conservation (Pikitch 2004). Its main goal was to introduce fisheries to an ecosystem-conservation based fishing activities, with the conservation of healthy marine ecosystems and the fisheries within them and the use of the precautionary approach when data is scarce. This Ecosystem Approach to Fisheries (EAF) highlighted the importance of improvement of selectivity on fishing techniques and gears and the development of new uses and markets for the accidentally taken products. This also presented the establishment of seasonal closures, bycatch quotas and landing obligations as feasible bycatch reduction measures. This

Ecosystem Based Fishery Management (EBFM) also called for minimizing impacts of fishing activities on marine ecosystems and mitigating unwanted interactions between fisheries and marine ecosystems by using available tools, such as fishery reserves, fishery restricted areas (FRA), no-take zones, MPAs and other spatial and temporal closures (Pipitone et al. 2014).

In the European Union, several RFBs that regulate fisheries in European and contiguous seas have been established by bilateral or multilateral agreements (*Table 4*), including RFMOs established under the provisions of the UN Food and Agriculture Organization (FAO) [GFCM and CECAF], or outside FAO framework [ICCAT, NASCO and NEAFC].

The only fishery policy which is being taken from national to international, this is, to the EU level, is the Common Fisheries Policy (Regulation (EU) No 1380/2013). The rest are only considered at national level. The Common Fisheries Policy, first introduced in the 1970, was a complex of rules created to manage European fishing fleets with the main goal of accomplishing a sustainable and responsible harvesting of living aquatic resources (both fisheries and aquaculture). The new CFP introduced in 2013 (Regulation (EU) No 1380/2013) implements the ecosystem-based approach to fisheries management, including avoidance/limitation of environmental impacts of fishing activities and unwanted catches.

The CFP integrates with other EU "conservation" directives (Habitats Directive, Birds Directive, MSFD), particularly through Article 11, contributing to the protection of the EU marine environment and the achievement of good environmental status by 2020. It introduces limited decentralisation in fisheries management as key parts of EBM, with regionalisation process stimulated through the establishment of stakeholder Advisory Councils. The achievement of this goal of "all European fish stocks producing at MSY by 2020" could face many obstacles. Nevertheless, as pointed by Link and Browman (2017), although the ecosystem-based management is complex, difficult to operationalize and with yet limited achievement, the progress is visible.

3.2 Technological innovations

Technical solutions to reduce bycatch include the development of modification of fishing gears in order to reduce bycatch rates and/or mortality. Different programs with the purpose of developing new fishing technologies have been originated through years, such as the National Oceanic and Atmospheric Administration's 'Bycatch Reduction Engineering Program' (NOAA Fisheries 2007), with more than a hundred funded projects till the moment.

Table 4: Fisheries Management Bodies in EU and contiguous seas.

Fisheries management bodies	**Established**	**Management targets**	**Specific targets**	**Bycatch management approach**
General Fisheries Commission for the Mediterranean (GFCM)	1997	General: Living Marine resources and aquaculture	Conservation and sustainable use of living marine resources, and sustainable development of aquaculture in the Mediterranean and in the Black Sea.	• Minimizing impacts of fishing activities on living marine resources and their ecosystems; • Adoption of management plans based on an ecosystem approach to fisheries; • Minimizing and mitigating unwanted interactions between fisheries and marine ecosystems and environment.
The North East Atlantic Fisheries Commission (NEAFC)	1980	General: Fishery resources	Long-term conservation and optimum utilisation of the fishery resources in the Convention Area, providing sustainable economic, environmental and social benefits.	• Adoption of conservation and management measures that address the need to minimise harmful impacts on living marine resources and marine ecosystems; • Accounting for the need to conserve marine biological diversity; • Examination of the overall effects of management policies on the fishery resources and other living marine resources and marine ecosystems.
Fishery Committee for the Eastern Central Atlantic (CECAF)	1967	General: Living marine resources	Sustainable utilization of the living marine resources by the proper management, and development of the fisheries and fishing operations.	/
North Atlantic Salmon Conservation Organization (NASCO)	1984	Specialised: Atlantic salmon	Conservation, restoration, enhancement and management of wild Atlantic salmon through international cooperation taking account of the best available scientific information.	• Identification and designating priority/key habitats for improvement; • Maintaining biodiversity; • Taking into account other biological factors affecting the productive capacity of Atlantic salmon populations, including predator-prey intaractions; • Protection of the current productive capacity of the existing physical habitat of Atlantic salmon; • Restoration the productive capacity of Atlantic salmon habitat which has been adversely impacted.

The International Commission for the Conservation of Atlantic Tunas (ICCAT)	1969	Specialised: Tunas and tuna-like species	Compiling fishery statistics from all entities fishing for these species, coordination of research, including stock assessment, development of scientific-based stocks management.	• Formulation of conservation and management measures relating to tunas and tuna-like fishes of the Atlantic Ocean
The Joint Norwegian-Russian Fisheries Commission (JointFish)	1974	General: Fish stocks	Development of eco-based fishing strategy and long-term, precautionary approach to harvesting strategies for the live marine resources in the Barents Sea and the Norwegian Sea.	*info not available*
EU The Common Fishery Policy	2013	General: Marine biological resources	Conservation of marine biological resources and the management of fisheries targeting them, including aquaculture and recreational fishery	• Implementation of ecosystem-based approach to fisheries management, including avoidance/ limitation of environmental impacts of fishing activities and unwanted catches; • Contribution to the protection of the marine environment, to the sustainable management of all commercially exploited species, and in particular to the achievement of good environmental status by 2020; • Adoption of measures in the event of a serious threat, requiring immediate action, to the conservation of marine biological resources or to the marine ecosystem resulting from fishing activities.
The International Council for the Exploration of the Sea (ICES)	1964 (1902)	General: Sustainable use of the oceans	Provision of the best available science for decision-makers to make informed choices on the sustainable use of the marine environment and ecosystems.	*not applicable*

Different bycatch reduction devices have been developed in the last years. Turtle excluder device (TED) was the key technological innovation for saving the Kemp's ridley sea turtle (*Lepidochelys kempii*) from extinction (*Figure* 8*a*; Lewison et al. 2003). Similarly, by the 2000s immature individuals of different fish species constituted the biggest portion of the catch in the overexploited Western Mediterranean, with the hake (*M. merluccius*) being the most affected species. In response to this situation, Sardà et al. (2004) applied different devices for immature individual catch reduction in trawling fishing gear (*Figure 8b*). The devices tested were composed of three types of different grids and one square-mesh panel. Results showed that the escape rate for all grids went from 50% to 90%. Therefore, the implementation of these devices could be a potential solution not only for hake, but for all fish species caught by trawling (Sardà et al. 2004).

Watson et al. (2005) investigated different ways to reduce sea turtle bycatch rates in pelagic longlines targeting swordfish and tuna from the North West Atlantic waters by substituting the commonly used J-shaped hooks for circle hooks with different degrees of offset (*Figure 8c*). Also, they analyzed the differences present between mackerel- and squid-baited hooks. This study demonstrated that the combined use of mackerel-bait and circle hooks with no offset resulted into a decrease in fishery-sea turtle interactions of 90% for loggerheads and 65% of leatherbacks without affecting negatively to the swordfish catch. Furthermore, the use of circle hooks caused a decrease in the mortality rates of bycatch since this hook type was commonly found hooked in the jaw or different parts of the body (fins, shoulders,

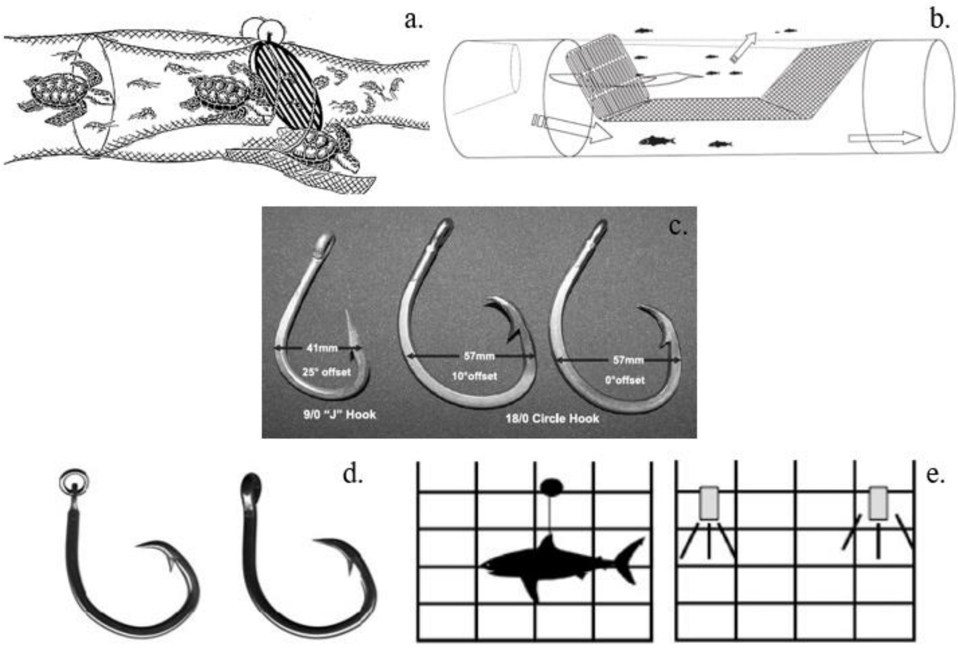

Figure 8: Technical solutions (a – Turte Excluder Device (TED), b – juvenile fish excluder grids (Sardà et al. 2004), c – J-shaped and circle hooks (Watson et al. 2005), d – ringed and non-ringed hooks (Piovano and Swimmer 2017), e – visual deterrents (Wang et al 2010)).

Table 5: Technological fixes created for reducing bycatch (data from Lewison et al. (2004a)).

Technological fix	Functioning	Fishery
Turtle excluder devices	A large metal grid in the neck of the net which physically excludes turtles while allowing the catch of shrimps	Trawl
Tori (bird scaring) lines	Keep seabirds away from baited hooks	Pelagic longline
Weighted lines	Faster sink of hooks out of reach of seabirds	Pelagic longline
Side-setting	Reduces the scavenging area by half	Pelagic longline
Line-setting devices	Immediate underwater positioning of hooks	Pelagic longline
Circle hooks	Reduce the frequency of deeply ingested hooks and limits gut perforation	Pelagic longline
Pingers	Acoustic devices that alert marine mammals of the presence of gillnets in order to avoid entanglement	Gillnet
Medina panels	Fine-mesh net aprons that reduce the probability of dolphin entanglement during net retrieval	Purse seine

armpits) instead in the gut. This made it easier for the fishermen to retrieve the hooks and proceed to a safe release of the alive animals (Watson et al. 2005).

The use of ringed circle hooks was determined not to be an effective measure to reduce bycatch of sea turtles and sharks in swordfish longline fisheries from the Mediterranean (Piovano and Swimmer 2017; *Figure 8d*). Bycatch rate resulted the same and regarding swordfish it lead to a catch of a higher number but smaller individuals.

The addition of different visual cues on gillnets in order to reduce green sea turtle (*Chelonia mydas*) bycatch was studied by Wang et al. (2010). The authors used shark shapes places along the gillnet, illumination of the net by LED lights and illumination of the net by chemical lightsticks (*Figure 8e*). Results indicated that shark shapes were the best sea turtle deterrent, but these also affected to the fishery catch. Nevertheless, the illumination of the net by both lighting methods gave similar sea turtle deterrence results and negligibly affected the catch, resulting into the effectiveness of this tool (Wang et al. 2010).

Many other technological innovations exist for bycatch reduction of different taxa (*Table 5*; Lewison et al. (2004a)).

3.3 Other tools

Besides these technological innovations there are also other ways to try to reduce bycatch and its mortality that include education, raising public awareness and building public support, including ecolabelling.

Eco-labelling was one of the most important actions which helped finding a solution to 'The tuna-dolphin conflict in the Eastern Tropical Pacific' (*Figure 9a*). The labelling of tuna cans with the 'Dolphin-safe tuna' concept made public to put pressure upon those fisheries still targetting on tuna-schools associated with dolphins, this way causing the cease of this activity (Hall 1998). Simultaneously, public encouraged fisheries to use non-dolphin involving methods, such as the purse-seining upon "log sets" or "schooling sets" (NOAA Fisheries 2016).

Many educational projects exist around the Mediterranean Sea, which are encouraged and founded by the European Commission. These include the programme teaching fishermen how to maintain alive on board and proceed to a safe release of by-caught sea turtles took place in different countries from the Mediterranean Sea by the Network for the Conservation of Cetaceans and Sea Turtles in the Adriatic (NetCet 2018; *Figure 9b*). For individuals caught by longlines, this program taught the importance of not pulling from the lines of the hooks, but to use a net to get the sea turtles on board. For trawling by-caught individuals, the procedure to follow consisted on keeping the individuals on board enough time for them to recover from the comatose state and later put back into the sea. This simple change in fishermen behaviour lead to a decrease of sea turtle bycatch mortality. Similarly, the Regional Activity Centre For Specially Protected Areas developed the 'Sea Turtle Handling Guidebook for Fishermen' (RAC/SPA 2001). This one reviews the biology of sea turtles,

a.

b.

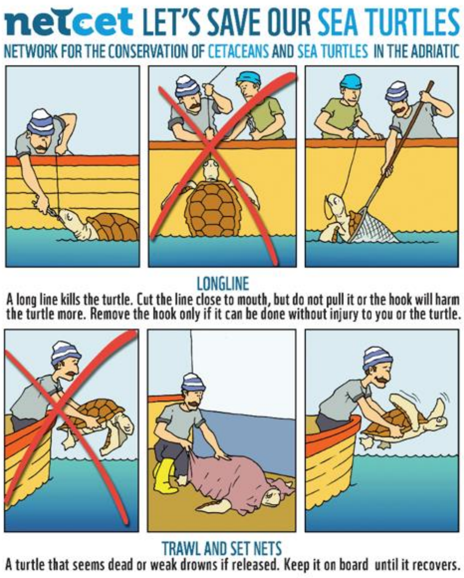

Figure 9: Other tools (a - raise of public awareness, b – educational programmes).

the species present in the Mediterranean, their major threats and specially the proper ways to act in different situation where sea turtles get caught by fishing gear.

Education among the public and programmes with the target on fishermen’s behaviour are both tools available for conservation in terms of bycatch and ecosystems.

4 BYCATCH: FUTURE SIGHT AND CONCLUSIONS

Bycatch is present in all fisheries and affects all kind of species. Because of this, it has become a major conservation issue in global fisheries in the last decades and it crucially needs to be managed, reduced and eliminated to the extent and as soon as possible.

What most threatens marine environment is not only the biodiversity loss caused by bycatch, but the loss of functions and services this event entails. Both ecosystem functions and services are positively correlated with the level of biodiversity present and thus ecosystem complexity (Duffy et al. 2007), which is synonym of ecosystem health. Decrease of biodiversity caused by bycatch results into decrease of resistance, resilience and recovery potential after disturbance (Levin and Lubchenco 2008). Since industrial fishing started, human being has been fishing down marine food webs (Pauly et al. 1998) and, if this was not enough, fishing gear development leading to a decrease of selectivity has resulted into every time bigger amounts of bycatch. Remarkable impacts of bycatch are the ones appearing when this affects key stone species such as sharks, marine mammals, sea turtles and seabirds, which often show ecologically important functions. These impacts go from species-specific to higher extent ones, affecting populations, communities and even whole ecosystems. If bycatch does not show any urgent change, we will be witnesses of the continuous and gradual degradation of the marine realm, observing every time poorer waters both in terms of marine life quantity and diversity. These reductions will be followed by the loss of functions and ecosystem collapses, point which not easily will have a way back.

This is also a problem of waste due to the millions of tons of fish discarded back to the water, together with the moral issue brought by this huge waste of animal lives. It is also related with economy, for economists, and public image, for fishermen (Hall et al. 2000).

The big solution to this problem is education, education about the huge issue bycatch is and how to take part on its solving process. Science world is already aware of how serious bycatch issue is, but this concern still needs to be raised among policy makers, decision takers, fishermen and public in general. Only with collaboration of everyone will this issue get solved. Making people aware of the huge impact human is having upon whole marine ecosystems and the consequences of this is the key for achieving a minimum level of conservation. Bycatch is just a small part of all the damage we are causing to the Earth but its consequences are not proportionally related, these are way bigger than what we can imagine.

Data gaps concerning bycatch are numerous and need to be filled with the best scientific and therefore reliable data. For achieving this, it is very important and necessary to have the support of the policy-makers and decision-takers. Result of this is the effort of the European Union is making in order to link fisheries with conservation in the Common Fisheries Policy, being bycatch a crucial part of the whole complex. At the moment, bycatch management is synonym of fishery management and therefore it should be an integral part of the sustainable, ecosystem based fishery. Conservation goals such as bycatch reduction need to be included in marine fisheries management on both international and national levels.

5 POVZETEK NALOGE V SLOVENSKEM JEZIKU

UVOD

Morski industrijski ribolov v grobem razdelimo glede na ribolovno orodje, ki je lahko aktivno ali pasivno. Aktivna ribolovna orodja so tista, ki jih plovila vlečejo za sabo. Mednje spadajo pridnene koče, pelaške koče in dredže ali ramponi. Na drugi strani pasivna ribolovna orodja ribiči postavijo v morje, kjer so le ta bolj ali manj statična. Mednje spadajo parangali, enoslojne in trislojne mreže ter kletke. Prilov v omenjenih ribolovnih orodjih se močno razlikuje, prav tako pa smrtnost naključno ulovljenih organizmov.

DEFINICIJA PRILOVA

Alverson in soavtorji (1994) so prilov opredelili kot kombinacijo naključni ulov neciljnih vrst, ki se vrnejo v morje ali zadržijo in uporabijo. Organizacija Združenih narodov za prehrano in kmetijstvo (FAO 2011) je prilov opredelila kot ulov, sestavljen iz osebkov neželjenih vrst in velikosti, Lewison in sodelavci (2004) pa so dodali še ulov osebkov neželjenega spola ali starostnega razreda.

STANJE PRILOVA

Prilov se je povečal hkrati z razvojem ribolovnih tehnologij, saj so le te v kratkem času izjemno napredovale. Napredek se je najbolj izrazil v povečanju ulovljenih količin rib, kar pa je imelo za posledico postopno zmanjšanje selektivnosti ribolovnih orodij. Prilov se pojavlja pri uporabi vseh ribolovnih orodij, vpliva pa na mnogo različnih vrst v morju. Še posebej izpostavljen je negativen vpliv na vrste, ki imajo v ekosistemih ključne vloge (plenilci na vrhu prehranjevalnih spletov, npr. morski psi).
Šele v zadnjih 50 letih, ko je ribolov postal izrazito industijska dejavnost, je prilov prepoznan kot eden od osrednjih problemov industrijskega ribolova. Stopnja prilova v razmerju s tarčnim ulovom je v nekaterih območjih tudi do 90%, pogosto pa znaša med 25% in 70%.

POSLEDICE PRILOVA

Najbolj neposredna posledica prilova je pogin naključno ulovljenih organizmov. Ob tem zaenkrat ni dobro raziskano, kaj se zgodi z organizmi, ki so preživeli in jih spustijo nazaj v morje.
Posledice povečane smrtnosti organizmov se izrazijo na populacijskem nivoju – zmanjša se sposobnost razmoževanja, spremeni se stopnja preživetja mladičev, spremeni seg enetska raznovrstnost, spremeni se velikost pri kateri so osebki spolno zreli, spremeni se starostna struktura. V primeru, da se ti negativni vplivi ne odpravijo, številnost populacij lahko upade do te mere, da postanejo ogrožene ali celo izumrejo.

UKREPI IN UPRAVLJANJE

Odgovorne institucije, kot so na primer državne vlade, meddržavne zveze (Evropska Unija) in mednarodna združenja (FAO), poskušajo reševati prilov na več načinov. Vključili so ga v svetovne, regionalne in nacionalne načrte upravljanja ribjih staležev.

Na nivoju Evropske Unije (EU) je prilov opredeljen v Skupni ribiški politiki EU, kjer so navedeni tudi ustrezni ukrepi za njegovo zmanjševanje. Države članice EU so dolžne v svoje zakonske aktih sprejeti programe upravljanja prilova vključno s predpisanimi tehničnimi ukrepi, ki bodo to zagotovili. Hkrati pa so dolžne spremljati učinkovitost teh ukrepov in nadzirati, ali se v praksi dejansko uporabljajo.

ZAKLJUČEK

Kljub vsemu temu, pa se ukrepi še vedno izvajajo regionalno. Mnoge morske vrste pa v svojem življenjskem ciklu uporabljajo obširna območja in lahko prečkajo celotne oceane med prehranjevalnimi in razmnoževalnimi območji. To pomeni, da dobro upravljanje prilova v eni regiji pomeni malo ali nič, če se v sosednji regiji upravljanje ne izvaja. Namen pričujoče naloge je bil pregled in analiza prilova v morskem ribištvu v preteklosti in sedanjosti v morjih Evropske Unije. Naloga vključuje tudi pregled mednarodnih dogovorov, pravnih podlag in tehničnih ukrepov za zmanjševanje prilova ter njihove učinkovitosti. V zaključku pa sem se opredelil glede mogočih scenarijev v prihodnosti.

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