Fish Discards Management in selected Spanish and Portuguese *métiers:* Identification and potential valorisation.

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Abstract

With the aim of promoting the responsible and sustainable management of marine resources, the European Union and the Food and Agriculture Organization of the United Nations (FAO) have established a set of international guidelines on by-catch management and reduction of discards. In this framework, the minimization of discards and the optimal valorisation of inevitable unwanted biomass are the main objectives of the optimal and efficient discards management network that has been developed in FAROS LIFE+ Project. According to FAO, in 2008, around 27 million tonnes of marine biomass were used for non-food purposes, these including fishmeal, fish oil, bait or high-added value compounds production by pharmaceutical or cosmetic industries. In this work, the most important discarded species by the selected *métiers* of interest for FAROS project have been analysed regarding possible valorisation options in a wide variety of sectors, including food products for human consumption. A protocol to easily determine the most suitable valorisation strategies for each of them has been also established. In order to carry out this approach, several factors as the status of stocks in the environment, the valorisation potential of each species or by-product and the amounts discarded by *métier* have been taken into account.

Keywords Fish discards; sustainability; valorisation alternatives; food & high-added value products.

1 Introduction

In 2008, nearly 81% (115 million tonnes) of world fish production was used for human consumption, while the rest (27 million tonnes) was directed for non-food purposes (FAO, 2010). From the later, seventy-six percent (20.8 million) was employed for fishmeal and fish oil production. The remaining (6.4 million tonnes) were used mainly as fish for ornamental purposes, bait, and pharmaceutical purposes as well as raw material for direct feeding in aquaculture, farm animals and pets. Improved processing technologies play an important role, among others factors, in the increase in the utilization of fish waste derived from the fish-processing industry.

Recently, there has been a considerable debate about the need for new uses for fish catches that may increase the interest on some species (actually discarded) and promote more sustainable fishing strategies together with principles of environmental-friendly industry practices/processes. Especially the recovery of chemical components from marine species is a promising area of research and development (Arvanitoyannis & Kassaveti, 2008). This solution can be useful for species actually also discarded.

General options for fish discards and by-products valorisation can be classified as follows: 1) Production of fishmeal, oil and silage; 2) Production of potential compounds of interest in various fields such as pharmacy, cosmetics, etc. and; 3) Food supplements and human food applications (direct use, surimi production, etc.). Some valorisation technologies for fish discards and wastes were already analysed in the previous BE-FAIR LIFE project (Alonso, Antelo, Otero-Muras & Pérez, 2010).

In general, and in order to achieve a reduction in the level of discards aimed by national and European administrations and reflected in the reform of Common Fisheries Policy (CFP), it is necessary to change the perception/attitude of the extractive sector actors towards the idea of keeping in the holds the whole catch (target species, by-catch and other marine organisms if they cannot be returned alive to the sea). In fact, the reform of

CFP enables fishermen to play an active role in designing measures to avoid by-catches in the first place and to land all commercial species that are caught. However, the implementation of this objective is expected to be difficult.

It must be pointed out that discarding practices are a key point of the Ecosystem Approach to Fisheries Management (EAFM). Far from being an easy issue, discarding practices relate to the core of fishing operations, from an economic, legal, and biological point of view. However, despite all these difficulties, there is a common agreement (among citizens, NGOs, the fishing sector, policymakers, scientist, etc.) that perceives discards as very negative and that effective solutions to this problem have to be implemented.

The Food and Agriculture Organization of the United Nations (FAO) has developed, in a recent report (FAO, 2010), a technical consultation to set international guidelines on by-catch management and reduction of discards. These guidelines intend to assist states and Regional Fisheries Management Organizations and Arrangements (RFMO/As) in the management of by-catch and reduction of discards in conformity with the FAO Code of Conduct for Responsible Fisheries (FAO, 1995). The scope of these guidelines is global, covering all fishing activities in all seas, oceans and inland waters. In this report (FAO, 2010) and in relation with the By-catch Management Planning (BMP), it is said that states and RFMO/As should ensure that BMP considers both best practices and a reduction of discards developed in cooperation with relevant stakeholders. Best practices should include, among others, the development of measures to meet these objectives, adapted to the characteristics of each fishery where by-catch and discard problems need to be addressed. Main FAO guidelines can be summarized as follows:

- To minimize potential by-catch through spatial and/or temporal measures;
- To minimize by-catch through modifications of fishing gears and practices;

- To maximize the release of alive by-catch while ensuring the safety of the fishing crew;
- To make the best use of unavoidable by-catch according to the guidelines described in the Code (FAO, 1995).

The optimal valorisation of inevitable by-catch was the main objective of the optimal and efficient discard management network that was developed in BE-FAIR and FAROS Projects (Antelo, Ordóñez, Franco-Uría, Gómez-Gesteira, Fernández-Canamero, Pérez, Castro, Bellido, Landeira & Alonso, 2011), co-funded under the LIFE+ Environmental Program of the European Union (LIFE08 ENV/E/000119 – www.farosproject.eu). The aim of this valorisation framework is to produce protein hydrolyzates, peptones, enzymatic mixtures, fish oil with a high content of polyunsaturated fatty acids (PUFA), other added-value biocompounds or high quality fish meal, being these products of interest for sectors such as aquaculture or food. In addition, some species could be excellent to be directly consumed either fresh or frozen.

In this work the analysis of the discards generated on selected metiers is presented. The main reasons for discarding of species/resources and valorisation options to minimise discards were identified. The previous analysis allowed us to outline a protocol for selecting the best valorisation alternative for each species, mainly focusing on food and bio-compound obtaining applications.

2 Methodology: Fishing ground and discard characterization

The cornerstone of the understanding of the fleets dynamic and the associated discards generation is to undertake the fleet segmentation by identifying homogeneous groups of fishing activity developed by vessel groups with similar technical features. The definition of these homogeneous groups, termed *métier* among other names in literature, contributes to design more efficient sampling schemes. In fact, it has been explicitly included in the new Community framework for the collection, management and use of data in the fisheries sector (EC Regulation No 199/2008), where the concept *métier* is defined as *a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterized by a similar exploitation pattern*.

In this work, the following *métiers* identified in the framework of FAROS project (Pérez, Prista, Santos, Fernandes, Azevedo, Ordóñez, Bellido & Fernández, 2011; Azevedo, Prista, Fernandes, Castro & Marin, 2011) have been considered for analysis:

1) OTB51: Bottom otter trawl fleet vessels authorized to fish in Community waters (OTB50), with base on Vigo and Marin (Northwest of Spain) targeting flat fish and, basically, operating in Subarea ICES VII. They provide high discards levels of, mainly horse mackerel (*Trachurus trachurus*), sea anemone (*Actinauge richardi*), boarfish (*Capros aper*), small-spotted catshark (*Scyliorhinus canicula*), megrim (*Lepidorhombus whiffiagonis*), blue whiting (*Micromesistius poutassou*), Atlantic mackerel (*Scomber scombrus*), haddock (*Melanogrammus aeglefinus*), red gurnard (*Aspitrigla cuculus*) and hake (*Merluccius merluccius*).

2) OTB11: Northern Spanish coastal bottom otter trawl fleet vessels (OTB10) targeting a variety of demersal species in ICES Divisions VIIIc and IXa-North. They provide high discard levels of Henslow’s swimming crab (*Polybius henslowii*), blue whiting (*Micromesistius poutassou*), small-spotted catshark (*Scyliorhinus canicula*), horse mackerel (*Trachurus trachurus*), blackmouth catshark (*Galeus melastomus*), and squat lobster (Galathea spp.).

3) OTB_DEF_02: Vessels of the bottom trawl fleet for demersal fish that operate along the year and off the entire Portuguese coast with hauls directed to a variety of species. Discards mainly consists of chub mackerel (*Scomber colias*), hake (*Merluccius merluccius*), blue jack mackerel (*Trachurus picturatus*) (occasionally with high percentages of Atlantic mackerel, *Scomber scombrus*), boarfish (*Capros aper*), pouting (*Trisopterus luscus*) and Henslow's swimming crab (*Polybius henslowii*).

Discarded fish species obtained in the above mentioned *métiers* can be mainly classified into three categories: 1) Species with low value or no value in the market; 2) Small sized species (under Minimum Legal Size - MLS), including young or juvenile, even if they have commercial value as adult and; 3) Species that cannot be retained on board due to legal reasons (Total Allowable Catch regulations, etc.).

Most of the species discarded in each identified *métier* have real commercial value in Spain and Portugal but they are discarded for various reasons: legal reasons related to the quota system, strategic or commercial reasons, lack of quality in the case of damaged or in poor specimens or in poor condition, etc. Priorities between different *métiers* (both Spanish and Portuguese) were established (Azevedo, Prista, Fernandes, Castro & Marin, 2011) according to their current level of discards and the consequent need to reduce them. These classification studies were essential for a better understanding of their respective fishing activities and discarding strategies.

In order to perform the specific discard analysis and associated valorisation alternatives/potential by species in each selected fishing unit (*métier)*, the following factors were taken into account:

- *Status of stocks in their habitat*: This factor has been analyzed first in importance, especially for certain species or species groups, such as skates or sharks. Negative status of some species hinders the valorisation or, at least, raises the question of its convenience. For some species, the actual lack of stock information has been also analysed.

- *Valorisation potential*: A review study has been carried out to identify the presence of certain valuable biocompounds and/or general the valorisation potential of each discarded species.

- *Total métier discard*: The amount of total discards by species can give an idea of the quantities of raw material available for valorisation, although these figures are approximate.

A complete list of discarded species was analyzed for each métier (OTB_51, OTB_11, OTB_DEF_02), studying their valorisation potential by taking into account the above mentioned factor in the fisheries of interest. This summary is presented next in Section 3.1. As a first example, and based on this analysis, several cartilaginous species, like blue skate (*Dipturus batis*), were identified to have low processing/valorisation interest. In fact, many cartilaginous fish stocks are currently in poor condition, based on recent evaluations of organizations such as ICES (Clarke, 2009). Therefore, many species are found in the "Red List" of the International Union for Conservation of Nature (IUCN, 2011). Regarding this source, as well as similar ones, the priority strategy to be considered for these species should be the minimization of discards and the release of captures alive to the sea, whenever this is possible (FAO, 2010; NAFO, 2011). As a final option and instead of throwing dead fish to sea, valorisation might be considered.

3 Valorisation strategies of discarded species of interest

The objective of ensuring the sustainability of increasingly scarce natural marine resources (called by the EU as *Blue Growth* – European Commission, 2012) implies the need to explore and exploit the possible valorisation of discarded biomass and to seek for new uses in the context of food, pharmaceutics and nutraceutics industries. This is in line with one of the main goals of this new global *Blue Growth* strategy defined by the EU: to make the best possible use of biological resources in a sustainable manner. This objective could be achieved through the development of resource-efficient primary production systems that foster related ecosystem protection and minimal environmental impact.

In the framework of this pursued sustainable and efficient scenario, *blue biotechnology* (specific objective of the Blue Growth strategy) deals with the exploration of marine organisms in order to design and develop new "on demand" compounds, in particular those responsible for certain bioactive or sensory characteristic of interest in the food and nutraceutics industries.

In this Section, and after a brief presentation of selected discarded species with real valorisation interest, the valorisation strategies defined in the last years by researchers in this marine valorisation/biotechnology field are compiled and reviewed, presenting them by type of application (extraction of biocompounds, food applications and fishmeal/oil/silage) and selected discarded species.

3.1. Selected discarded species and stock status in the considered métiers

Table 1 summarizes the main characteristics of discarded species in the different *métiers* that can be considered as potential raw material for valorisation purposes through existing identified valorisation strategies/adding-value chains (both in related literature and at real processing/operating scale).

As it can be seen in Table 1, *horse mackerel* is the most discarded species in selected Portuguese and Spanish *metiers* (10,850 t/year). This species, together with the *blue whiting* (3,500 t/year) and *Atlantic mackerel* (3,180 t/year), are discarded due to different reasons associated with the fishery. In this case, despite the potential of these species for food applications (direct human consumption), the duration of Great Sole Bank fishing trips threats adequate conservation on board, resulting on the non-commercial value reflected in Table 1 for these species on *métier* OTB_51. Regarding ships fishing in coastal waters (OTB_11, OTB_DEF_02), these species are usually discarded due to low catch volume and/or economic strategies like high-grading, a practice which consists in only bringing the best quality fish ashore, by selective harvesting (discarding the rest at sea).

Another species with commercial interest is the *greater silver smelt* that is included in the list of trade names in Spain. This species exhibits an important discard level for the *metier* OTB51 (900 t/year), being particularly susceptible to rapid local depletion due to its aggregating behaviour (ICES, 2010). By taking into account the advice of ICES for 2011, a reduction in catches should be considered, in the light of the survey data indicating a recent decline.

The dynamic behaviour of fisheries also conditions discarding levels, as in the case of *boarfish*. Nowadays, an increase in the abundance of this species in the Northeast Atlantic has been detected (White, Minto, Nolan, King, Mullins & Clarke, 2011). As a consequence, the considered Spanish trawling fleets catch and discard large quantities (up to 4,600 t/year) due to no quota availability for this species. The same reason for discarding applies for *haddock* (2,650 t/year in Great Sole), a species with high commercial interest in worldwide markets. Especially in these cases, a legislation change leading to new quota assignments would be necessary prior to the retention on board of these unwanted captures and to the study of their possible use or management.

Regarding discarded shark species as the *small-spotted catshark* (3,600 t/year) and the *black-mouthed dogfish* (710 t/year), both of them are classified as *Least Concern* in the *Red List of Threatened Species* of IUCN, because overall population trends appear to be stable. Thus, there is no evidence that the global population has declined significantly (IUCN, 2011), although population catches and trends should continue to be monitored. However, in the stocks evaluation carried out by ICES (ICES, 2010), the state of the demersal elasmobranch small-spotted catshark was considered unknown (in the Celtic Sea and West of Scotland as well as in the Bay of Biscay and Iberian Waters). The ICES advice for 2011 and 2012 is to maintain catch at current levels for Celtic Sea and West of Scotland, while keeping landings below 1,700 t/year in the case of the Bay of Biscay and Iberian waters.

It must be mentioned that black-mouthed dogfish is widely distributed in the Northeast Atlantic. As a consequence, this species is usually taken as by-catch in demersal trawl and longline fisheries, and generally discarded. However, some specimens have market value and can be retained and sold, although more biological and population data of this species (i.e. through ICES evaluations) would be required in order to attain a sustainable future exploitation (Olaso, Velasco, Sánchez, Serrano, Rodríguez-Cabello & Cendredo, 2004).

Other species like the *red gurnard* has been recently included (year 2013) in the list of trade names in Spain due to the increasing interest detected in some markets for its direct human consumption. As a consequence, it seems that the trend is towards keeping it on board in those fleets where this species is being nowadays discarded (trawl fisheries). Around 1,725 t/year are still discarded by the Spanish and Portuguese *métiers*. Grey gurnard (*Chelidonichthys gurnardus*) is a similar species that could have almost the same valorisation options.

Regarding invertebrate species, the second most discarded species based on total biomass volume is sea anemone (8,500 t/year), a sea urchin with no current commercial interest in Spain and Portugal, being this fact the only cause of discarding. Besides, this species is not currently included in international conventions and/or European protection laws, and its recovery might be of interest for the fleets based on potential rising prices and quantities per haul.

In addition, around 3,000 t/year of *Echinoderms* are discarded in the considered fishing areas (Great Sole bank and coastal waters of the Iberian Peninsula), with increasing commercial interest for direct human consumption and biocompounds extraction (see Subsection 3.2 for further information).

Finally, *Henslow's swimming crab* and *squat lobster* are crustaceans that are included in the list of trade names in Spain, although they are still scarcely known species. Important amounts of valuable biomass (up to 1,914 t/year) of these crustacean species are discarded by the considered fleets with important valorising potential as described in the next subsection.

3.2. Valorisation potential

3.2.1. Extraction of biocompounds

Potential applications related with extraction of marine compounds with several uses, mainly in medical and pharmaceutical sectors (as well as several industries including cosmetics, agriculture, food, sewage, etc.), are presented for the following species/groups.

- <u>Sea anemone (*Actinauge richardi*)</u>

Several important natural products for medical uses have been found in marine invertebrates, such as sponges, bryozoans, tunicates and ascidians (Trejos, Šturdíková & Šturdík , 2009; Lloret, 2010). As an example, the first marine compound to enter human clinical trials against cancer was the Diademnin B, isolated from a tunicate over 20 years ago. This fact opened the way for wide variety of drug candidates isolated from marine organisms (Rinehart, Gloer, Hughes, Renis, Mcgovren, Swynenberg, Stringfellow, Kuentzel & Li, 1981).

Actinaria or sea anemones are marine invertebrates without physical defence and a simple immune system (Marginet, 2008), but they produce some compounds like actinoporins that are important against potential predators of the sea anemones, as it happens in other marine invertebrate (Caldwell & Pagett, 2010). Fedorov, Dyshlovoy, Monastyrnaya, Shubina, Leychenko, Kozlovskaya, Jin, Kwak, Bode, Dong & Stonik (2010) confirmed that actinoporin RTX-A from *Heteractis crispa* might exhibit, at least partially, cancer-preventive and anticancer cytotoxic properties.

Cao, Foster, Lazo & Kingston (2005) reported the isolation of four compounds of a new class of xenicane diterpenoids isolated from an anemone. These compounds are of high interest based on their cytotoxicity, antimicrobial and antibacterial activities in trials executed in both rabbit and human cell neutrophils.

It must be mentioned that only around 10% of the estimated number of species within *Cnidaria* and *Echinodermata* has been examined for natural product bioactivity (Marginet, 2008). Therefore, the available research potential is very high. In fact, several new antitumor agents isolated from marine tunicates are under study and development by companies in NW Spain (Galicia). Some examples of anticancer products and drugs obtained from tunicates and ascidians are presented by Trejos, Šturdíková & Šturdík (2009), including well known drugs such as Ecteinascidin 743 (Yondelis) approved in 2007, Dehydrodidemnin B (Aplidine) in a phase of clinical trial or some others in preclinical evaluation phases such as Diazonamide A.

- <u>Echinoderms</u>

The echinoderm genera identified are not included in the commercial list applicable in Spain (Secretaría General del Mar, 2010). However, some species from *Holothuria spp.* and *Stichopus spp.*, traditionally harvested for direct human consumption in specific regions, have recently been investigated as a source of biomedical components (Alfonso, Tacoronte & Mesa, 2007). Under this approach, extracts from sea cucumber (common name for species included in genera as *Holothuria* and *Stichopus*) are included into easy-to-consume formats, such as capsules and tablets by several companies in the nutraceutics sector (Swanson Vitamins. Now Foods, NutriSea, etc.).

Holothurians contain a variety of substances, including chondroitin sulphate (CS) and glucosamine as cartilage building blocks (Alfonso, Tacoronte & Mesa , 2007) together with bioactive substances with anti-inflammatory and anti-tumor activity properties such as glycosphingolipids (Hirata, Zaima, Yamashita, Nogochi, Xue & Sugawara, 2005). Thus, the composition of sphingoid bases prepared from sea cucumber is different from that derived from mammals, showing their cytoxicity against human colon cancer cell lines in Sugawara, Zaima, Yamamoto, Sakai, Noguchi & Hirata (2006).

The high pharmacological potential of triterpene glycosides isolated from several species of sea cucumbers has been confirmed (Matranga, 2005). These glycoside compounds showed antifungal, anti-inflammatory and cytotoxic properties. Moreover, antifungal activity of crude extracts of body fluid and body wall from the Mediterranean species of sea cucumber (*Holothuria polii*) has been also reported (Ismail, Lemriss, Ben Aoun, Mhadhebi, Dellai, Kacem, Boiron & Bouraoui, 2008). Finally, it must be mentioned that saponins and terpenoids are specifically extracted from *Echinodermata*. In this context, the capability of echinoderms for synthesizing substances useful as new medicaments has been suggested (Matranga, 2005), although most echinoderm species are still unexplored in terms of valorisation potential

- Small-spotted catshark (*Scyliorhinus canicula*)

Chondrichthyes, such as *S. canicula* are characterised by cartilage skeleton, which is mainly composed by the polysaccharide chondroitin sulphate (CS). Several results showed that CS obtained from this species has a chemical structure compatible for the formulation of pharmaceutical products (Gargiulo, Lanzetta, Parrilli & De Castro, 2009). Besides, GAG (glycosaminoglycans), other galactosaminoglycan, may be isolated from fresh cartilaginous tissues of this species (Gargiulo, Lanzetta, Parrilli & De Castro, 2009).

Skin valorisation of this species may also be of interest because this tissue contains some compounds with useful properties. For instance, dermatan sulfate (DS) can be isolated from *Scyliorhinus canicula* skin (Dhahri, Mansour, Bertholon, Ollivier, Boughattas, Hassine, Jandrot-Perrus, Chaubet & Maaroufi, 2010), or from other marine species (Yamagata & Okazaki, 1974; Sakai, Kim, Lee, Kim, Nakamura, Toida & Imanari, 2003; Mansour, Dhahri, Bertholon, Olliver, Bataille & Ajzenberg, 2009; Mansour, Dhahri, Hassine, Ajzenberg, Venisse, Ollivier, Chaubet, Jandrot-Perrus & Maaroufi, 2010). This compound is the major glycosaminoglycan (75% of the polysaccharide fraction) found in shark skin. This tissue represents about 11% of the total body of sharks (Nomura, 2004), containing a percentage of dermatan sulphate of 0.3% (dry weight). DS has higher anticoagulant effect than porcine DS. Based on studies developed by Dhahri, Mansour, Bertholon, Ollivier, Boughattas, Hassine, Jandrot-Perrus, Chaubet & Maaroufi, (2010), marine dermatan sulphate constitutes a potentially useful drug in anticoagulant therapy.

The wide range of biological functions of several glycosaminoglycans (GACs) as chondroitin sulphates (CSs), dermatan sulphate and keratin sulphate (KS), as well as their properties and possible therapeutic applications in the treatment of serious diseases, are questions of current research (Volpi, 2006).

Chondrichthyes skin can also be an excellent source of collagen, with application in food and pharmaceutical sectors (Kittiphattanabawon, Benjakul, Visessanguan, Kishimura & Shahidi, 2010). Gelatine and collagen extraction from other under-utilized species such as *P. glauca* have been described in literature (Limpisophon, Tanaka, Weng, Abe & Osako, 2009; Alonso, Antelo, Otero & Pérez, 2010).

In terms of availability of potential raw material for valorization purposes, *S. canicula* is one of the most discarded species in the considered *métiers* (4,600 t/year), with potential of producing 368 t of cartilage for chondroitin sulphate obtaining and 496 t of skin for GAG synthesis. Its valorisation could be optimized by considering the possible interest of liver to produce oils (squalene). For this use, pollutant concentrations in the organ prior to the valorisation study must be determined to prevent the introduction of these pollutants in the human food chain.

- <u>Black-mouthed dogfish (*Galeus melastomus*)</u>

In many fisheries, the main reasons of shark capture were the finning and the obtaining of liver oil (Vannuccini, 1999). This product is specifically used in the manufacture of cosmetics and pharmaceuticals (Hareide, Carlson, Clarke, Clarke, Ellis, Fordham, Fowler, Pinho, Raymakers, Serena, Seret & Polti, 2007) due to its properties as a source of important nutrients for health maintenance (Szostak & Szostak-Wegierek, 2006). Livers may represent between one third to one fifth of total body weight, and about 70-80% of liver can be converted into oil depending on the species. Squalene and other compounds can be found in large quantities in the oil obtained from several shark species (Blanco, Sotelo, Chapela & Pérez-Martín, 2007).

Up to 142 tonnes of livers can be obtained from the 710 t/year of *Galeus melastomus* captured what represents a large amount of oil (106.5 t, approximately). However, several studies revealed the presence of contaminants in the oils obtained from this species, since liver is the organ where pollutants tend to preferentially accumulate (Storelli & Marcotrigiano, 2002; Storelli, Storelli & Marcotrigiano, 2003).

- Other cartilaginous species

Several cartilaginous species discarded in the studied *métiers* might have certain commercial interest, mainly in the food sector, as described in Table 2. However, in many cases, these species are discarded or, during processing, can generate a relatively high quantity of by-products that have certain compounds of interest in many applications and fields. The objective of fishing vessels for species like sharks and skates must be the whole use of all captured specimens (NAFO, 2011) if the prevention of its capture or the release of live specimens to the sea were not possible. Potentially, the complete use of these species is possible by combining food use (backs, belly flaps, fillets, wings, etc.) with other applications (liver, head, skin, etc.) as it is indicated by some studies (see Table 2 for more details). Besides, new "bioactive compounds" for medical and pharmaceutical purposes can also be obtained, resulting on an additional potential for increased utilization of specific entrails in a near future (Blanco, Sotelo, Chapela & Pérez-Martín, 2007).

- Crustacean species

The natural polysaccharide "chitin" is synthesized by a number of living organisms (Jayakumar , Prabaharan, Nair, Tokura, Tamura & Selvamurugan , 2010). In the case of the industrial production of chitin/chitosan, the most exploited sources of chitin are crab and shrimp shells offal of several commercial species (Hayes, Carney, Slater & Brück, 2008), since only around the 65% of shrimp is edible (Bueno-Solano, López-Cervantes, Campas-Baypoli, Lauterio-García, Adan-Bante & Sánchez-Machado, 2009). Chitosan, the deacetylated product of chitin, has been found to be a biocompatible natural polymer, biodegradable, nontoxic, biofunctional and with antimicrobial characteristics (Dutta, Tripathi, Mehrotra & Dutta., 2009; Jayakumar, Prabaharan, Nair & Tamura, 2010), very useful for biomedical and foods applications (Carreira, Gonçalves, Mendonça & Coelho, 2010).

Various species of the genus *Munida spp*. have been studied for obtaining chitin and chitosan (Muzzarelli, Muzzarelli, Cosani & Terbojevich, 1999). Other discarded species in the studied *métiers* such as *Nephrops norvegicus* (Norway lobster), have been studied for the production of chitin and chitosan (Beaney, Lizardi-Mendoza & Healy, 2005). Average chitin contents obtained throughout the year from *N. norvegicus* shell waste were 214.17 ± 15.63 g/kg (Morrow, 2002). For this species, different forms of extraction (chemical techniques and alternative methods) have also been investigated. Although the chitin content is different according to the raw materials considered, its extraction and quality depends on the method employed (Beaney, Lizardi-Mendoza & Healy, 2005). Therefore, environmentally-friendly innovative methods could be an effective pre-treatment in the process of obtaining high quality chitin (for instance, for medical applications).

For some crustacean species, certain annual variability of Atlantic common crab (*Cancer pagurus*) and *Polybius henslowi* has been observed in some fisheries (Woll, Van der Meeren & Tuene, 2006), including the considered *métiers*. Therefore, this fact should be considered when studying new uses, apart from human food. Price differences have also been observed depending on the fisheries, which could also affect the chances of recovery and/or selection of priority areas for implementing valorisation strategies.

Apart from chitin (15-50%), shells also contain proteins (20–40%), calcium carbonate (20–50%) and carotenoids (10%) (Kurita, 2006). Specifically, shrimp and crab shell wastes are an important source of carotenoids (Hayes, Carney, Slater & Brück, 2008) and the use of biological extraction methods of carotenoid pigment of shellfish waste prior to chitin conversion has been investigated (Hayes, Carney, Slater & Brück, 2008).

Astaxanthin is one of the most important types, since it presents higher antioxidant, anticancer and pigment properties than other carotenoids (Goswami, Chaudhuri & Dutta, 2010).

Chitin and carotenoid extraction from crustaceans has been tested, in relation to the NW Spain (Galician) fleet, by IIM-CSIC (Marine Research Institute – Spanish Council for Scientific Research), for species like *Polybius henslowi* (Henslow's swimming crab), *Munida rugosa* (Rugose squat lobster) and *Bathynectes maravigna*, along with by-products such as heads and other exoskeletons of commercial species (Carmen G. Sotelo & Ricardo Pérez-Martín, personal communication; García-López et al., under review). Based on these studies and on the amount of discards estimated in Spanish and Portuguese *métiers* (907.12 t of non-edible portions of *P. henslowi* and 324.8 t in the case of *Munida spp.)* some potential production figures of added-value compounds can be estimated (Table 3).

- <u>Pelagic fish species</u>

These species have been studied as a source of several enzymes from viscera (Blanco, Sotelo, Chapela & Pérez-Martín, 2007). Important digestive enzymes such as proteases (aspartic protease pepsin, serine proteases, trypsin, chymotrypsin and elastase) could be obtained from fish viscera. Biochemical characterisation of *B. boops* (Bogue) trypsin showed that this bioproduct can be used as a possible biotechnological tool in fish processing and food industries, although further research is needed to determine its specific properties (Barkia, Bougatef, Nasri, Fetoui, Balti & Nasri, 2010).

Bougatef, Balti, Nasri, Jellouli, Souissi & Nasri (2010) noted that some properties of other fish trypsins such as sardine *(S. pilchardus*), gray triggerfish (*B. capriscus*) and common smoothhound (*M. mustelus)* are similar to those from *B. boops*. Common or related applications could be set for this compound from several sources. However, the amounts of bogue discarded in the selected *métiers* should be considered low.

3.2.2. Food applications

In this case there are two main options for valorising discards: direct human consumption (with the introduction of new species in markets) or production of specific added-value bioproducts for the food sector.

- Sea anemone (*Autinauge richardi*)

Several species of sea anemones and other ascidians are consumed as seafood in several countries (Sawada, Yokosama & Lambert, 2001; Hirose, Ohtake & Azumi, 2009). Specimens are collected manually, being their culinary use very popular in some coastal regions, where they are consumed mainly in restaurants, because auction sales are mainly aimed at this catering sector. For example, *Anemonia viridis*, of high nutritional value (González, Caride, Lamas & Taboada, 2001), has market potential in Spain and other countries as high-quality product. Furthermore, pharmaceutical and therapeutic properties and uses (laxative and diuretic) have been defined for these species (Voultsiadou, 2010).

- Boarfish (*Capros aper*)

Organoleptic and nutritional properties together with food applications of boarfish are being currently studied by IIM-CSIC (Carmen G. Sotelo & Ricardo Pérez-Martín, personal communication) and ICTAN-CSIC (Madrid, Spain). This study includes some conservation (ice-cooling methods on board or frozen storage) and processing applications for this species (filleting, handling, etc.) with the aim of introducing boarfish for direct human consumption in Spain and other European markets instead of its main present application (fish meal). The lack of previous commercial initiatives for boarfish could be related with the lower presence of this species in the Northeast Atlantic fisheries (Farrell, Hüssy, Coad, Clausen & Clarke, 2012). Nevertheless, during the last years, boarfish were caught in increasing quantities in both pelagic and demersal fisheries (O'Donnell, Farrell, Saunders & Campbell, 2012), existing now a TAC control system for it. Unfortunately, this system is without allocation in the case of Spain and Portugal, which means that this species is still a problem of discarded biomass.

Regarding future actions, specific promotion of this new species to consumers, in this case in Spain and Portugal, is likely to be required (Stockhausen, Officer & Scott, 2012).

- Echinoderms

Some species of sea cucumbers are highly consumed in Asia and other western countries (Anderson, Flemming, Watson & Lotze, 2011). In fact, Asian demand has been so high during last years that these species have been collected from U.S.A. and other countries (e.g., Australia, Philippines) to guarantee an adequate supply in this market. This fact has made prices to increase not only in the Asian but also in the international market (Hamel, Conand, Pawson & Mercier, 2001). As a consequence, the high demand of these marine organisms has caused over-exploitation of certain fisheries (Bruckner, 2006). In order to increase their production, the promotion of their cultivation has become an important part of mariculture activities in China (Jiaxin, Bueno & Lovatelli, 1990; Lovatelli, Conand, Purcell, Uthicke, Hamel & Mercier, 2004).

The special properties of cooked *Stichopus japonicus,* one sea cucumber species, could be related with the body wall mainly composed of highly insolubilized collagen fibres (Saito, Kunisaki, Urano & Kimura, 2002). In Spain, the species *Stichopus regalis* (*Royal cucumber* or "cohombro de mar real", "espardenya" in Spanish), is a very popular gastronomic product in some Mediterranean regions. The status of its stock is being currently studied by IEO-Spain in order to include these species into the list of commercial species in Spain. Sea cucumbers could also be of interest for aquaculture purposes (Sicuro & Levine, 2011).

Even though their ecological and economic importance, the available knowledge on these species populations is, in general, scarce, being this type of stock assessment studies important for their proper management and exploitation (Friedman, Eriksson, Tardy & Pakoa, 2011). In a recent FAO report, Toral-Granda, Lovatelli & Vasconcellos (2008) warned about the overexploitation of sea cucumbers populations in parts of Africa, Indian and Pacific oceans where these species are almost exhausted. The report states that specific management plans are required, with several necessary measures such as area and /or time closures, monitoring of reserves, etc.

- Red gurnard (*Chelidonichthys cuculus*)

Red gurnard is common in UK waters and, since 2007, its popularity has increased in this country since it is sold as gourmet food at premium prices in fish markets, fishmongers and restaurants. The Marine Conservation Society (MCS) includes red gurnard in its list of recommendations since 2006 and the "Good Fish Guide" aims to promote its consumption to conserve fish stocks of other popular white fish. This species, together with other fish and crustacean species commonly caught and consumed annually in Italy, were studied regarding their importance as a dietary source of PUFA (Passi, Cataudella, Di Marco, De Simone & Rastrelli, 2002). According to landings statistics (ICES), the annual catches of red gurnard in the North Atlantic have been 4,055 tonnes in 2009. However, there are uncertainties in landing data since some nations do not discriminate between red, tub and grey gurnard.

The proposal of alternatives for utilization as food could help to make a proper use of the 1,725 t discarded in the *métiers* considered in this work. The promotion of this species can be achieved by collaboration with associations of restaurants, chefs and similar organizations and stakeholders in the catering sector (Stockhausen, Officer & Scott, 2012).

Grey gurnard (*Chelidonichthys gurnardus*) is other species that is also discarded and could have similar valorisation potential as red gurnard (human consumption, focused in catering sector).

- Great silver smelt (*Argentina silus*)

This species is usually consumed fresh or in fish meal production (Froese & Pauly, 2011). This species (among a total of 22 under-utilised fish and shark species) was analysed as a source of dietary w-3 PUFA (Dunne, Cronin, Brennan & Ronan, 2010) in order to assess potential health benefits to the consumers. On the other hand, the Icelandic ban on discarding, coupled with the establishment and running of a "bycatch bank" for a number of years from 1989 (Clucas, 1997), demonstrated to fishermen and fish traders that there were markets for unusual species of fish caught as by-catch. Those new species would be introduced and promoted among consumers when necessary. As a result, several fish as *Argentina silus*, showed high potential for market expansion.

- Discarded crustaceans

According to a recent research project (Carmen G. Sotelo & Ricardo Pérez-Martín, personal communication), in which properties of some crustacean species were analyzed, *Polybius henslowii* could not be useful as a resource for human consumption due to its high cadmium content, although it could be used for obtaining chitin. On the contrary, potential for the production of human food was observed for *Munida spp.*, since their organoleptic characteristics are similar to Norwegian lobster, and it can be considered a versatile and quality product. Moreover, crustaceans are marine organisms that are characterized by a high non-protein nitrogen content, which gives them a strong and characteristic flavour and odour (Baek & Cadwallader, 1997). As a result, one direct use for discarded crabs in the food sector could be as flavourings and concentrates to be added as an ingredient into other foods or meals, or also they can be incorporated into animal feed, in which the taste of crab is a desired characteristic.

- Horse mackerel, blue whiting and Atlantic mackerel *(T. trachurus, M. poustassou and S. scombrus*)

It has been shown that recovered proteins and oil from underused fish species and by-products retain functional and nutritional properties for human food products (Gehring, Davenport & Jaczynski, 2009). Consequently, there is a high interest in increasing the use of fish proteins as a food ingredient due to their high nutritional value (Sanmartín, Arboleya, Villamiel & Moreno, 2009). Added-value products like surimi or fish sauce are some of the traditional food applications options for the valorisation of fish proteins which might be employed in the case of mentioned discarded species in the cited *métiers* (Venugopal & Shahidi, 1995).

An increasing interest in developing high-added value fish products like minces made from fatty fish has been detected (Rodríguez-Herrera, Bernández, Sampedro, Cabo & Pastoriza, 2006). This is due to the fact of their high levels of long chain PUFAs, such as eicosapentaenoic acid (EPA, C20:5 n-3) and others (Eymard, Baron & Jacobsen, 2009). The three main discarded species under study (horse mackerel, blue whiting and Atlantic mackerel*)* specifically exhibit such valorisation potential.

Moreover, these species have shown some potential to be used as a raw material for surimi production. In fact some of the problems associated with the production of surimi with fatty species have been addressed by different studies (Eymard, Baron & Jacobsen, 2009; Rodríguez-Herrera, Bernández, Sampedro, Cabo & Pastoriza, 2006). In the case of blue whiting there have been already some commercial experiences of obtaining this product in Norway, France and Russia (Trondsen, 1998). The surimi market prices are a crucial condition for the implementation of this solution by the fleets (Trondsen, 1998). This economic factor will be important in the considered *métiers* too.

It must be mentioned that several studies on improving the properties and features of these products and possible changes in processes have been developed, such as the addition of hydrocolloids improving texture characteristics of the final product (Pérez-Mateos & Montero, 2000; Yoshie-Stark, Tsukamoto, Futagawa, Kubota & Ogushi, 2009; Pin, Laca, Paredes & Díaz, 2010; Nolsøe, Marmon & Undeland, 2011; Pérez-Mateos & Montero, 2000). The good results obtained could lead to feasible utilisation of these discards by fleets. Others changes can be considered as an opportunity to make future surimi production more sustainable with a better utilization of the raw material (Nolsøe, Marmon & Undeland, 2011).

3.2.3. Meals and silage from marine species

- Fish meal

By-products and several fish species of low or non-commercial value are often used to produce oils, fish meal and silage. In fact several fisheries have experience in selling part of the by-catch to fish meal factories together with usually unmarketable species that are also employed as feed for aquaculture (Venugopal & Shahidi, 1998).

Great silver smelt (*Argentina silus*) is widely distributed in the North Atlantic. This species is currently exploited mainly for the production of fish meal and protein (Jangaard, Regier, Claggett, March & Biely, 1974) since this use has been studied for decades (Mackie & Hardy, 1969). The results regarding lipid and amino acid composition indicate that fish meal produced from this species would be nutritious and it has relatively high oil content.

In the case of other species, such as *Trachurus trachurus*, *Micromesistius poutassou* and *Scomber scombrus*, a great volume of their catches are traditionally used to produce fish oil and meal (Rodríguez-Herrera, Bernández, Sampedro, Cabo & Pastoriza, 2006), because food applications are hinded by their poor stability during conservation, as previously mentioned in this work.

Boarfish (*Capros aper*) has recently become the target of a directed commercial fishery for fishmeal purposes located on the Irish West coast and exploited by Irish and Danish vessels. Boarfish landings from both fleets are now providing raw material for Danish fishmeal industries and replacing other traditional species (White, Minto, Nolan, King, Mullins & Clarke, 2011). Meal obtained from North Sea boarfish is used for salmon feed. In the case of the Scottish salmon industries, boarfish (among others) is considered now a new and alternative feed fishery, with around 50,000 tonnes harvested annually.

Some pilot experiences carried out in Vigo (Galicia, Spain) for obtaining boarfish meal have shown that 160 g of fish meal were obtained from 1kg of this species with 60.14% of protein content (Technical paper, 2009). Therefore, the potential amount for fishmeal production from the discarded fraction of this species in the considered Spanish and Portuguese *métiers* (4,600 t/year) is about 736 t /year.

In the case of Portuguese *métiers*, other similar species such as *Macroramphosus scolopax* are also discarded and the use of these discards for meal production can represent around 35 t/year of meal.

Fish silage is other possible product made from fish waste materials from different marine species that could be adequate for use as an ingredient in aquaculture feeds (Blanco, Sotelo, Chapela & Pérez-Martín, 2007).

- Crustacean meal (*Polyibius Henslowii*)

Discarded crustaceans can also be the raw material for high quality meals which can be used for feeding several aquaculture species (Cho, Park, Kim & Yoo, 2008). Crustaceans are a good protein source, and they can be especially suited for marine organisms which include these organisms in their natural diet (Kalinowski, Robaina, Fernández-Palacios, Schuchardt & Izquierdo, 2005). One example of this approach is the meal obtained from the red crab (*Pleuroncodes planipes*) used in diets aimed for whiteleg shrimp (*Litopenaeus Vannamei*) and yellowleg/brown shrimp (*Penaeus Californiensis)* farming. It has been shown that these species increase the growth rate when this crab meal replaces the 100% of fish meal, concluding that the red crab meal may contain a growth promoter (Goytortua-Bores, Civera-Cerecedo, Rocha-Meza & Green-Yee, 2006).

In addition to the previously mentioned use of *Polybius henslowii* to obtain chitin, the production of meal from this species has been investigated in Vigo (Spain) by IIM-CSIC in the framework of several research and demonstration projects. As a main result of this experience it can be concluded that 200 g of high-value meal (66.69 % of crude protein and 9.54 % of fat content) can be obtained from 1 kg of *P. henslowii*. The application of this high quality meal on diet formulation for octopus aquaculture has been tested in Galicia, showing good preliminary results.

However, the cadmium content of *P. Henslowii* may prevent this application, and therefore, a previous heavy metals content analysis should always be performed.

3.3. Valorisation potential ranking

Valorisation alternatives have been detailed in this work by species, with the aim of promoting the sustainable management of more than 43,000 t of biomass discarded per year in the considered *métiers* (Spanish and Portuguese fleets operating in Great Sole and coastal waters). The rest of discarded species, inappropriate as raw material for identified valorisation strategies by different reason (i.e. the studied factors of stock situation reflect a dangerous situation for the species, the valorisation potential and/or discarded amounts per year are not sufficient to create/maintain in the long term a high-added value chain, etc.), should be also quantified in order to know the total discarded biomass in a given *métier*. This full analysis of discarded species will allow to define the appropriate measures and/or policies to reduce/eliminate this unacceptable loss of valuable marine resources towards a sustainable scenario of the fishing activity.

Two valorisation options have turned out to be the most important for the analyzed species: 1) Extraction of compounds with potential properties in important application sectors (especially medical and pharmaceutical) and; 2) food application for direct human consumption in the case of specific species.

An assessment protocol of the valorisation potential of the studied species, by type of possible use, is shown in Table 4. In this table, a 3-score indicates that this is an optimal solution for the species based on the reviewed literature, with potential benefits for the target fleet. For ratings of 2, the species has potential in this area, although other applications could be more interesting and/or a more specific investigation may be required. Rating of 1 indicates little and no interest (-) based on the literature review performed.

By taking into account the total analyzed species, around 70% have potential in the extraction of some marine specific compounds, whereas a 50% could be destined to direct human consumption.

Potential for extraction of biocompounds has been observed for the three large groups of marine organisms analyzed (Echinoderms, Crustacean and Pelagic species), although a specific study by species have not been performed, since the information regarding these species is not always available on board (for example in the case of Echinoderms).

Regarding food applications, other complementary uses like added-value food products or additives production are possible in the considered *métiers.*

Some of the studied species like boarfish, Henslow’s swimming crab and red gurnard are considered suitable for valorisation purposes on a near future. As already mentioned, the abundance of boarfish in the Northeast Atlantic appears to be increasing in most regions. Besides, a recent interest in red gurnard has been detected in some specific markets and, in the case of Henslow's swimming crab, several potential and possible compatible uses have been identified. Based on these reasons, among others, the aim for the fishing sector should be to try to increase the consumption of these species. In this framework, monitoring programmes should be conducted to obtain data on biological parameters for stock assessment purposes according to sustainable fishing in European fisheries.

4 Conclusions

As highlighted in this work, there is a common and positive agreement (among citizens, NGOs, the fishing sector, policymakers, scientist, etc.) that identifies discards as very negative and that solutions have to be implemented. In this framework of promoting the responsible and sustainable management of the European fishing activity, the European Commission developed a number of actions directed to the development of policies to reduce unwanted by-catches and eliminate discards in European fisheries, as well as to make the best possible use of the captured resources avoiding its waste, including unavoidable discards generated in some fisheries (New Common Fisheries Policy, the Blue Growth Strategy).

Any valorisation strategy defined for the analyzed discarded species with no current commercial value or discarded due to other reasons could contribute to achieve a responsible fishing activity and to implement basic principles of industrial ecology (Erkman, 1997; Huppes & Ishikawa, 2011), objectives of FAROS project. The aim of this emergent research and development line is to obtain high-added value products of interest in the food and medical sectors.

In this work it was shown how sessile marine species (i.e. those that are not able to move and that are usually permanently attached to a solid substrate) caught by the Spanish and Portuguese fleets may contain compounds with several biomedical applications. Therefore, the next challenge will be the on board identification and quantification of such species in order to establish further valorisation alternatives. In addition to these initiatives, sustainable management plans would be necessary for this type of organisms, since such species are found on the seabed, a shared ecosystem vulnerable to bottom fishing gears.

The Spanish and Portuguese fishing sectors may start, in the short to medium term, contacts with distributors to sale some species (as red gurnard, boarfish, etc.) in European food markets in which it is well known that demand exits for them. In addition, in the medium to long term, it would be positive to introduce these new species in their own markets since consumption of fresh/frozen fish in Spain and Portugal is a very important part of the local traditional diets.

For other pelagic species with more presence in markets, as horse mackerel and Atlantic mackerel, the first strategy for discards reduction will include: a) to avoid high-grading practices; b) to solve conservation issues on board as a first step on the valorisation chain (fish in bad conditions is not marketable and therefore discarded); and even c) to modify legislative aspects as the actual quota system which involves discarding to comply with legislation, etc. Pérez et al. (2011) pointed out that guarantying convenient financial compensation for the eventual retained catch losses (initially sustained by fleets) is one of the key aspects for a successful reduction of discards, and especially of small-sized fish.

In this work it was presented that many discarded species can be used as raw material with different potential applications. The proper final use of discards could be coordinated and/or selected in an optimal and systematic way accordingly to the proposed valorisation ranking potential protocol (Table 4).

It must be also mentioned that sustainable valorisation of discards will have a very positive effect on the reduction of environmental impacts, since the quantity of species that are discarded both on board and on shore will be significantly decreased. In addition, these valorisation strategies could contribute to reduce pressure on traditional marine resources in Atlantic waters, some of them currently overexploited. Moreover, the implementation of real sustainable valorisation strategies is crucial to reduce environmental impacts related to some specific processes, as chitosan extraction (Beaney, Lizardi-Mendoza & Healy, 2005). FAROS project is also concerned about this issue and thus, once the initial operation conditions of valorisation processes are established, impacts associated with the different process steps and operating scenarios will be assessed by using environmental indicators, like LCA (Life Cycle Assessment) or EF (Ecological Footprint).

Finally, note that not all proposed valorisation alternatives are easy to implement in practice since both raw material needs and the technological requirements for designing and for starting up them are different. For instance, valorisation technologies to extract biocompounds from discarded species we just described will require higher investment costs as opposed to simpler alternatives such as production of fish meal. On the other hand, it is a fact that the prices for these biochemicals will be much higher than fish meal (in monetary units per kilogram), while big quantities of biomass would be require to produce only a few grams or kilograms of product. As a final conclusion, the analysis of design, scale-up and economic viability of proposed valorisation strategies for considered discarded species is the target of future research by the authors.

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List of tables:

Table 1.

OTB51						
Common name	**Scientific name**	**Commercial value**	**Status of the stock**	**Discards reason**	**% of Total Discard**	**Total discard (t/year)**
Horse mackerel	*Trachurus trachurus*	No	OK[1]	Conservation difficulties	16.5	10,000
Sea anemone	*Actinauge richardi*	No	--	No commercial	14.7	8,500
Boarfish	*Capros aper*	No	--	No commercial	7.2	4,400
Echinoderms	*Echinodermata*	No	--	No commercial	5.1	3,000
Haddock	*Melanogrammus aeglefinus*	Yes	OK	No Spanish quota	4.4	2,650
Small-spotted catshark	*Scyliorhinus canicula*	No	Least concern[2]	No commercial	4.3	2,600
Blue whiting	*Micromesistius poutassou*	No	Overexploited[1]	Conservation difficulties	4.2	2,500
Atlantic mackerel	*Scomber scombrus*	No	OK[1]	Conservation difficulties	3.9	2,300
Red gurnard	*Chelidonichthys cuculus*	No	--	No commercial	2.3	1,400
Greater silver smelt	*Argentina silus*	No	--	No commercial	1.5	900

OTB11						
Common name	**Scientific name**	**Commercial value**	**Status of the stock**	**Discards reason**	**% of Total Discard**	**Total discard (t/year)**
Henslow's swimming crab	*Polybius henslowii*	No	--	No commercial	12	1,240
Small-spotted catshark	*Scyliorhinus canicula*	No	Least concern[2]	No commercial	9.7	1,000
Blue whiting	*Micromesistius poutassou*	Low	Overexploited[1]	High-grading	9.7	1,000
Horse mackerel	*Trachurus trachurus*	Low	OK[1]	Low catch volume	8.3	850
Black-Mouthed dogfish	*Galeus melastomus*	No	Least concern[2]	No commercial	6.9	710
Atlantic mackerel	*Scomber scombrus*	Low	OK[1]	Minimum Legal Size & High-grading	6.4	660
Squat lobster	*Munida spp.*	No	--	No commercial	4.9	580

OTB_DEF_2						
Common name	**Scientific name**	**Commercial value**	**Status of the stock**	**Discards reason**	**% of Total Discard**	**Total discard (t/year)**
Boarfish	*Capros aper*	No	--	No commercial	8.2	227
Atlantic mackerel	*Scomber scombrus*	Low	OK (ICES)	High-grading	7.9	218
Henslow's swmming	*Polybius henslowii*	No	--	No commercial	3.4	94

[1] ICES. Status of Marine Stocks (2011). http://www.eea.europa.eu/data-and-maps/indicators/status-of-marine-fish-stocks/status-of-marine-fish-stocks-8

[2] The IUCN Red List of Threatened Species (2013) http://www.iucnredlist.org/

crab

Table 2.

Discarded species	Valorisation	Stock status (IUCN)	Other comments	Amounts
Bluntnose sixgill shark *(Hexanchus griseus)* (Wetherbee and Nichols, 2000; Bakes et al., 1995)	The lipid composition of ***liver oil*** was studied for this species. Basically composed (70%) of diacylglyceryl ether (DAGE) that is nowadays a lipid with increasing commercial interest.	Considered by IUCN as ***Near threatened***. Widely distributed world-wide.	Several traditional uses (e.g. meat and liver oil in Australia). Additionally, it has been used for salted and dried food products, as well as for fish meal and pet foods.	The shark's liver is about 18% of total body weight (approximation made based on figures from several shark species). The percentage of oil in liver is ≈ 50-60% w/w.
Thornback ray *(Raja clavata)* (Murado et al., 2010)	***Cartilage*** of this species is useful for obtaining Chondroitin sulphate (CS). The production of CS from cartilage of this species has been optimized, with low consumption of reagents and high purity obtained. The obtaining of highly purified CS was also defined.	Considered by IUCN as ***Near threatened***. In the last years, lower landings in the northern part of the East Atlantic were recorded. However, these reductions are lower than those reported for other large rajids.	Although this species is being discarded in low volumes in the analyzed métiers, valorisation is interesting because it is one of the species of skates with greatest interest in human food.	The presentation of this species in the market is, in most of cases (90%), only as skate wings. Generated by-products represent around 75% of the total weight. This by-product is constituted by cartilage of the central part of the skate and the skin.
Rabbit fish *(Chimaera monstrosa)* (Calis et al., 2005)	Pure products (mainly oils) extracted from the ***liver*** are suitable for cosmetic / nutraceutic purposes and for human consumption. There is an increasing interest in obtaining dietary supplements for human consumption derived from the liver oil of this species.	Considered by IUCN as ***Near threatened***. It has a stable population trend.	The main uses are the same as shark species as *Hexanchus griseus.* This species is taken in deep water trawl fisheries in the Northeast Atlantic. It is landed as a component of discarded by-catch.	Approximate amounts of raw material and potential product are similar as for the case of *Hexanchus griseus.*

Table 3.

Discarded species	Valuable bio-compound (g product/kg of species)	Potential amount of products obtained from total annual discards in selected *métiers* (kg/year)
Henslow's swmming crab *(Polybius henslowi)*	Chitin: 5 Carotenoids: 0.0040	4,520 5.28
Squat lobster *(Munida spp.)*	Chitin: 30.8 Carotenoids: 0.0063	10,000 3.65

Table 4.

Species/Organisms	Assessment of Potential Applications		
	Food application: **Direct human consumption**	**Medical & pharmaceutical:** **Extraction of biocompounds**	**Complementary uses:** **Surimi, meals, etc.**
Sea anemone *(Actinauge richardi)*	2	3	-

Boarfish *(Capros aper)*	3	-	2
Echinoderms	2	3	-
Small-spotted catshark *(S.canicula)*	1	3	2
Black-Mouthed Dogfish *(G. melastomus)*	1	3	2
Other cartilaginous species	1	3	2
Red gurnard *(A. cuculus)*	3	-	2
Greater silver smelt *(Argentina silus)*	3	-	2
Horse mackerel *(T. Trachurus)*	2	1	3
Blue whiting *(M. poutassou)*	2	1	3
Atlantic mackerel *(S. scombrus)*	2	1	3
Henslow's swimming crab *(P. henslowii)*	-	3	2
Squat lobster *(Munida spp.)*	3	2	1
Bogue *(B. boops)*	2	3	1