AQUAFISH 0.0 INTERREG Atlantic Area 2021-2027 Project EAPA_0062/2022

Inventory of biomass volumes in the Atlantic Area
By-products and bycatch in aquaculture and fisheries

WP 1 - Activity 1

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Target audience

AA Joint Secretariat	
Partnership	
Associated partners	
Media	
Public	

Means of delivery

E-mail	
Website	
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Lead partner for deliverable:

Contributing partners:

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CONTENTS

Table of Content

Table des matières

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Table of Acronyms

Acronym	Definition
ABAPP	Breton fish products buyers association
ABP	Animal by-products
ARDITI	Regional Agency for the Development of Research, Technology and Innovation
BIM	Ireland's Seafood Development Agency
BtoB	Business to Business
BtoC	Business to Client
CCI	Chamber of Commerce and Industry
CDPMEM29	Finistère Departmental Committee for Maritime Fisheries and Marine Farming
CEVA	Technological and innovation centre for seaweed valorization
CFP	Common Fisheries Policy
CIPA	Interprofessional Committee for Aquaculture Products
CRCBN	Northern Brittany Regional Committee of shellfish farming
CRCBS	Southern Brittany Regional Committee of shellfish farming
CRPMEM	Regional Committee for Maritime Fisheries and Marine Farming
DGAMPA	French General Directorate for Maritime, Fisheries and Aquaculture Affairs
DGAV	Portuguese General Directorate of Veterinary
DGRM	Portuguese General Directorate of Natural Resources, Safety and Maritime Services
EC	European Commission
EMFAF	European Maritime, Fisheries and Aquaculture Fund
EU	European Union
FAM	FranceAgriMer
FAO	Food and Agriculture Organization
FEMAS	Irish Feed Materials Assurance Scheme
FTE	Full-Time Equivalents
GDP	Growth Domestic Product
HOG	Head On, Gutted
IMTA	Integrated Multi-Trophic Aquaculture
INE	Portuguese National Institute of Statistics
IPMA	Portuguese Institute for Sea and Atmosphere
ISS	Irish Sea Spray company
IUEM	European University Institute for Sea Research
MAPA	Spanish Ministry of Agriculture, Fisheries and Food
MNHN	French National Museum of Natural History
MSC	Marine Stewardship Council
ONRB	French National Biomass Resources Observatory
PAI	French Intermediate Food Products
PETR	Rural Territories Cooperation Scheme for public authorities
R&D	Research and Development
SFPA	Sea Fisheries Protection Authority
SIH	Fisheries information system
SIN	Seafood Innovation Network
SMPPC	Joint association of Cornouaille Fishing and Marina Ports
UK	United Kingdom
WP	Work Package

Table of Figures

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Table of Tables

1. SUMMARY

Fishing and aquaculture are traditional activities in the Atlantic Area, with marine resources being a strong asset for them. The production processes of these sectors provide as a result not only the food products available for final consumption, but considerable amounts of by-products and bycatch which are discarded or used in low added-value applications, and which in some cases, represent an asset which can play a key role on the development of new food products of high added-value.

AQUAFISH0.0 aims to stimulate the sustainable production, processing and consumption of innovative seafood, based on a circular-economy approach that will use by-products and bycatch of the aquaculture and fisheries industries, and that will raise awareness of the need to implement policies to reduce food losses and waste (zero-waste philosophy) both among consumers and producers.

The first phase of the project focuses on research and development for the creation of innovative food products from by-products and bycatch of the aquaculture and fisheries industries, including waste reduction in product processing, and life-cycle treatment through innovative techniques. In order to do this, a series of activities are carried out to first identify the most relevant by-products and bycatch volumes in aquaculture and fisheries in the regions where the project will be implemented (Andalusia in Spain; Eastern and Midland Region and Northern and Western Region in Ireland; Brittany in France; Algarve, Lisboa and Região Autónoma da Madeira in Portugal), that will form the basis of the new food products developed by the project (circular economy approach).

2. INTRODUCTION

This report aims at presenting a common methodology to estimate the quantity and quality of by-products and bycatch volumes in aquaculture and fisheries in the 4 Atlantic Area countries. The objective is to try to obtain a picture of the main potentials for the development of innovative food products from aquaculture and fisheries bycatch and by-products in the different territories as well as the constraints to be considered in the production processes in any region of the partnership, setting the basis for the further collaboration in transnational development and piloting projects.

The methodology to collect the data was tested in one territory per country involved in the project. On the one hand, the methodology focused on the elaboration of an inventory or a register of information about by-products and bycatch volumes in the Atlantic Area at a national level. Partners gathered information from stakeholders and access to available data in the four countries (national and regional repositories). On the other hand, a needs analysis of industry players in aquaculture and fisheries was established to identify capacities, bottlenecks and challenges for the development of the new products with a circular-economy approach. This enabled the project partners to establish guidelines aimed at public authorities regarding the registration of information of this kind of products.

Finally, one focus group was organized in each country (4 focus groups in total), also involving all the AQUAFISH0.0 partners in each territory.

In compliance with the Project and Work Package 1 – Activity 1 objectives, this report aims at :

- presenting the estimations of biomass volumes carried out in each country to register **bycatch** and by-products
- describing the methodology used to reach these first results
- presenting case studies to better understand best practice and levers, risks and issues of existing circular initiatives and the value chain of marine by-products
- drafting general guidelines aimed at public authorities regarding the registration of information of this kind of products

This corresponds to the deliverables for WP 1 – Activity nr 1 listed in the project's description and to output RC 083.

3. ESTIMATION OF BIOMASS VOLUME

3.1 Methodology to estimate biomass volumes

General Observations

In the context of overexploitation of marine resources and an ever-increasing consumption of aquatic products, the application of the circular economy concept to the fisheries and aquaculture sectors appears essential.

A closer look at global consumption of aquatic products (both marine and freshwater) reveals that it has more than tripled since the 1950s (from 6 kg per capita to approximately 21 kg per capita) (FAO, 2022).

Globally, in 2019, the proportion of fish populations not being exploited at a biologically sustainable level was around 35,4%, compared to 10% in 1974 (FAO, 2022).

It therefore seems crucial to take action to ensure a sustainable access to this food resource. The circular economy stands out as one of the existing solutions to address this issue by maximizing the value of available resources.

The circular economy is defined as a "system that maintains the value of products, materials, and resources in the economy for as long as possible and minimizes waste generation. This means a system where products are reused, repaired, remanufactured, or recycled" (European Union, 2023a).

Various valorization pathways are available for marine by-products. From their use in agronomy to their application in the pharmaceutical industry, these by-products can be classified based on their added value and the absorption capacity of each market (Figure 1).
Two main types of by-products can be distinguished:

- those from production such as sorting discards, anomalies and unsold auction items,
- and those from the processing industry, including heads, skins, bones, and bivalve shells.

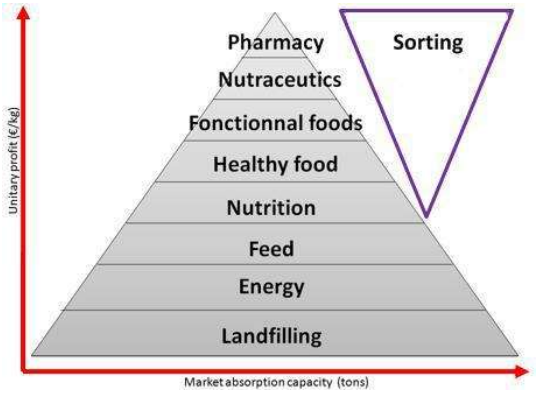

Figure 1: *Trends on food waste valorization (source: Bergé, 2008).*

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Regarding this pyramid, it is quite easy to distinguish between two main categories of valorization (Penven, 2014):

- mass valorization, which uses large volumes of by-products according to flexible specifications to obtain products with low added value (energy, agronomy, animal feed, etc.),
- niche valorization, which uses small volumes of by-products according to stricter specifications to obtain products with higher added value (pharmaceuticals, nutraceuticals, cosmetics, etc.).

In the fisheries sector, by-products generally correspond to the unused but recoverable parts produced during various processing operations (Dumay, 2006). This represents between 30% and 60% of the animal, depending on the species. For a fish, this includes the head, skin, central bones, trimming waste, viscera, liver and sometimes eggs (Figure 2). For crustaceans or mollusks, this may include the shell, cooking juice, etc.

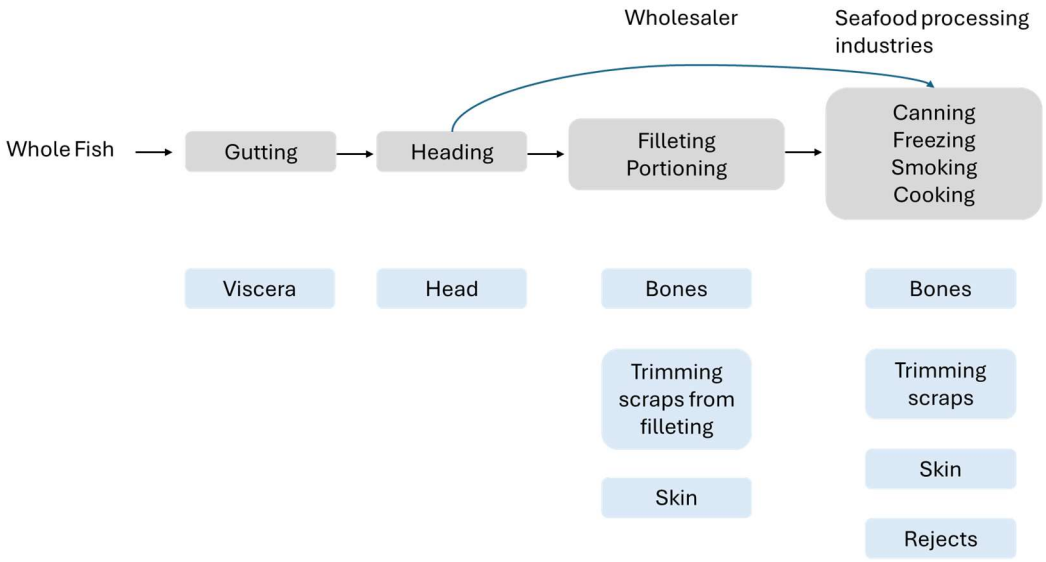

Figure 2: *Diagram of seafood products and co-products manufacturing (source: Réséda, 2017).*

Working throughout different countries requires a common understanding of the scope of the inventory and definitions, as well as common challenges:

- ***Data is collected in different ways in each country***

Existing databases and collection methods must be characterized and analysed before data can be used for bycatch and by-product estimation. Recent data is not always available and complete.

- ***Some countries have no available data on specific types of biomasses considered by the project***

According to the registration in place, some types of biomass are not registered or consolidated under different categories according to countries.

- ***Restricted access to data***

In some countries, data is available as open access, but others require a preliminary authorization to access it. Access to data can be requested but granted on a case-by-case basis.

- ***Definitions of by-products/subproducts/bycatch vary according to the country***

The European legislation ("Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives", 2024) gives the following definition of by-product, co-product and sub-product:

By-product (synonym of sub-product): a by-product is a substance or object, resulting from a production process, the primary aim of which is not the production of that item, may be regarded as not being waste referred to in point (1) of Article 3 of the Directive 2008/98/EC but as being a by-product only if the following conditions are met:

(a) further use of the substance or object is certain;

(b) the substance or object can be used directly without any further processing other than normal industrial practice;

(c) the substance or object is produced as an integral part of a production process;

(d) further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

Co-product: a co-product is a product produced together with another product.

However, the use, understanding and definition of these novel terms can vary greatly according to countries, stakeholders and degree of expertise in this field. It was thus key to establish common definitions and scopes to work together on this activity.

We will not refer to **co-product** for this estimation, since according to the European legislation and definition, co-products are voluntarily produced alongside the main production.

By-product in the Aquafish project: In this activity of the Aquafish project we will use by-products in the sense of the European legislation referred above, regardless of its destination (human consumption or not). According to various national regulations, by-products not qualified for human consumption should fall into the waste or sub-product category. However, in the scope of biomass estimation, and considering this is a new field of study, we have resolved to use the term by-product for any of the biomass raw materials produced and studied, to assess the full scope of the potential resource that could be valorized.

By-products include different elements according to the country: it can designate discarded elements that stem from transformation or processing such as in Ireland or start at threading such as is the case in France.

The following generic definitions (Figure 3) were set as a common understanding between the project's partners:

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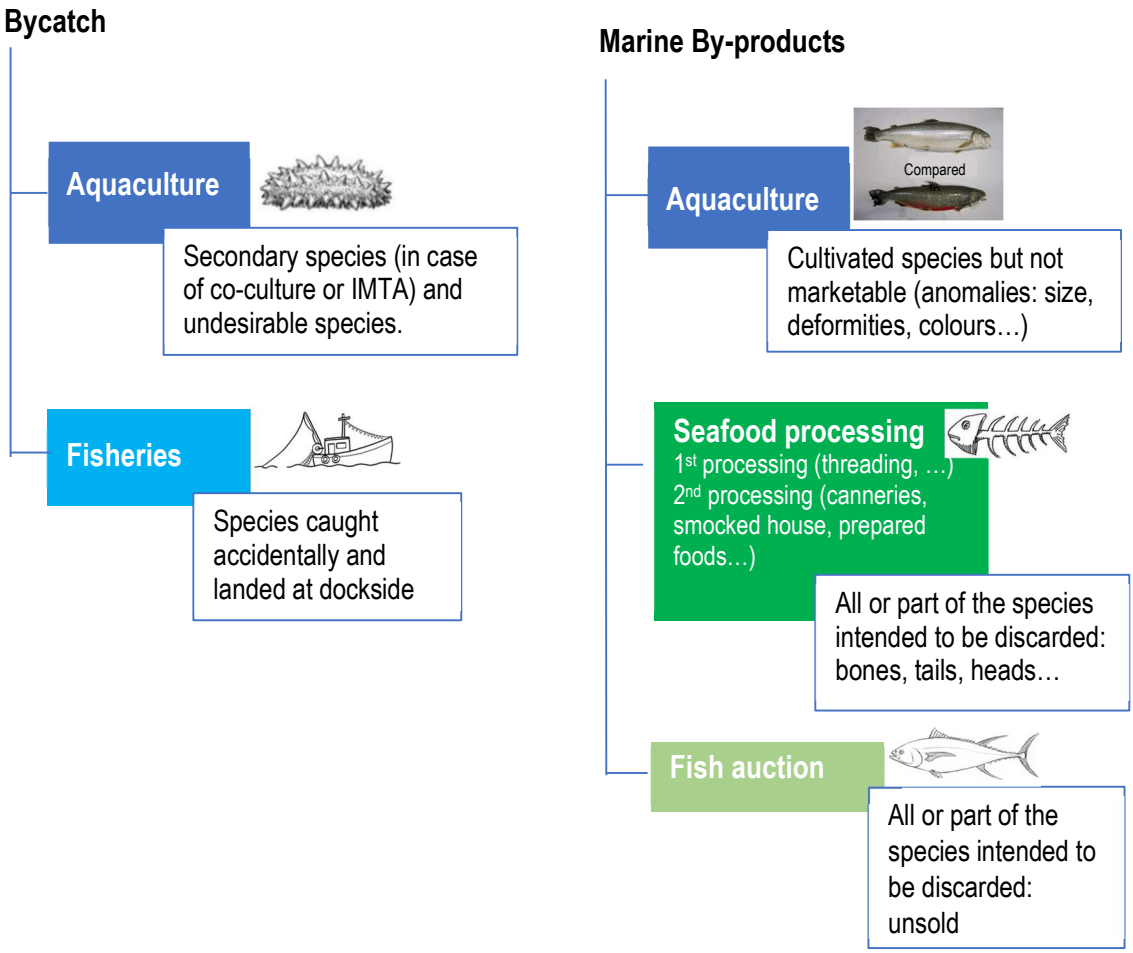

***Figure 3**: Diagram of seafood products and co-products manufacturing (source: Réséda, 2017).*

As shown in Figure 3, bycatch in aquaculture includes all secondary species (e.g., in the case of co-cultures and IMTA) and undesirable species. In fishing, this refers to species accidentally caught and landed at the dock.

Marine by-products generally correspond to any part or the entirety of the species intended for discard. They therefore encompass different types of products. In aquaculture, this includes farmed species that cannot be marketed due to anomalies (size, deformities, colour, etc.). In seafood processing, this includes any part or the entirety of the species intended for discard: bones, tails, heads, etc. In first processing, this corresponds to outputs occurring from filleting for example, or in second processing, to what comes from canneries, smokehouses, or prepared food industries. Unsold products from fish auctions are also considered by-products.

Biomass data was gathered from the following industries:

As shown in Figure 4, producers of by-products include aquaculture, the fishing fleet, IMTA (Integrated Multi-Trophic Aquaculture), and the seafood industry. Additionally, in English, at least two categories are distinguished: "bycatch" (or incidental/accidental catch) and "by-product" (the equivalent of a co-product).

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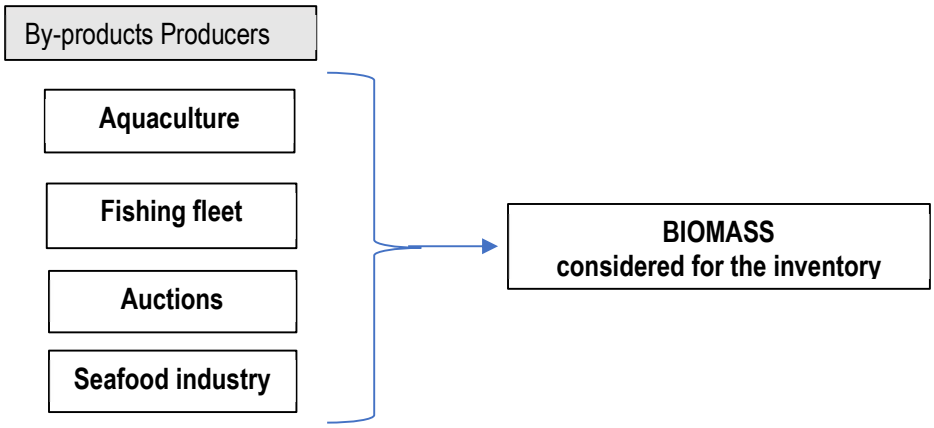

Figure 4: Definition of bycatch and marine by-products used in Aquafish project.

More visually, Figure 5 presents a flowchart of the entire value chain, showing the various sources that generate bycatch or marine by-products.

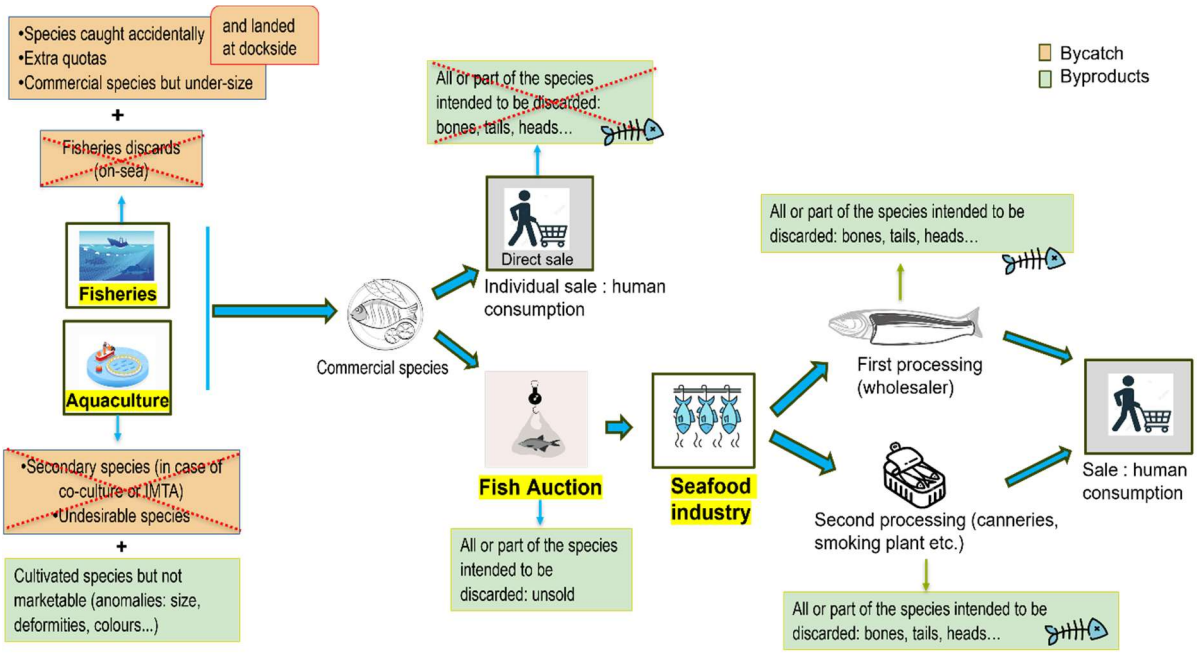

Figure 5: Flowchart of the entire value chain, showing the various sources that generate bycatch or marine by-products.

The following selection was applied to define the scope of the inventory:

Biomass taken into account in the inventory methodology

- Residues of fish from processing
- Unsold fish from auctions
- Seaweeds
- Species with anomalies to be discarded
- Mollusks, shellfish, crustaceans (whole or part) discarded
- Bycatch (and landed at dockside)

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Biomass not taken into account in the inventory methodology

- Shells
- Marine bio-waste from catering
- Marine bio-waste from fishmongers (as retailers)
- Household waste

The biomass studied is not limited to biomass adequate for human consumption such as was initially planned, since this would reduce the scope of the study and available data.

Moreover, the total biomass of macroalgae is studied as part of AQUAFISH0.0, whether it comes from algaculture or harvesting/fishing. Macroalgae are considered more as a secondary species rather than a by-product or bycatch.

Use of direct and indirect methodology

In order to gather the relevant data, indirect and direct methods were used to reach an estimation of biomass volumes:

- Direct surveys were carried out where data was available for analysis
- Indirect estimation methodology was applied when data was not directly available, using conversion coefficients applied to landed volumes, transformation rates and the analysis of existing reports

All partner countries carried out this estimation at a national scale. Some have also chosen to conduct this estimation on a regional scale:

- In France, the study will focus on Brittany
- In Spain, the study will focus on Andalusia
- In Portugal, the study will focus on Algarve.

3.2 France

In nearly 30 years, the French fishing fleet has lost 53% of its vessels, decreasing from 8 771 professional fishing boats registered in the Community Fishing Fleet Register (FPC) in 1990 to 4 163 in 2020 (SIH, Ifremer, 2022). Of these 4 163 vessels, 1 310 are located along the Mediterranean coast, 1 281 in the North Sea and English Channel, and 1 572 along the Atlantic coast. In 2021, the maritime professional fishing sector employed 13 777 people directly as fishermen, including 6 140 in small-scale fishing. Between 2020 and 2021, the sector experienced a 9% decline, losing 1 749 fishermen.

Although technologically advanced, France has not increased its small-scale production in aquaculture, which remains steady at approximately 6 000 tons of marine fish per year. Currently, eight species of marine fish and shellfish are farmed in France, listed in decreasing order of importance: seabass, gilthead seabream, salmon, meagre, sole, turbot, and penaeid shrimp. The number of businesses practicing aquaculture in mainland France is 3 145, employing just over 11 000 full-time equivalents (FTEs) (Vizagreste, 2021). In 2021, French aquaculture production amounted to 194 000 tons in final sales, representing € 811 Million.

In addition to its fishing fleet, France is the second-largest European producer of aquaculture products (from marine and freshwater aquaculture) after Spain. The primary aquaculture activities in France (Figure 6) are shellfish farming, fish farming, and algae cultivation (in marine environments or on land).

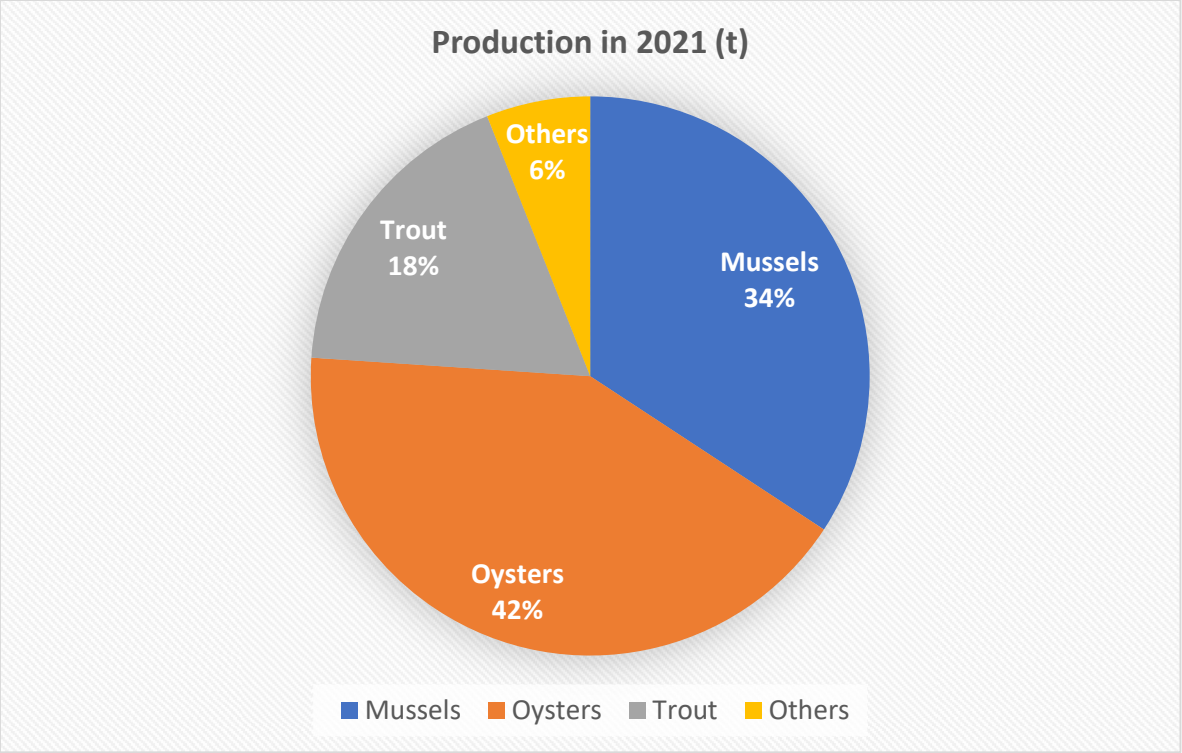

***Figure 6**: Breakdown of aquaculture production (in tons) in 2021 (source: vizagreste).*

In France, as in Europe, several estimations of marine by-products have been conducted. These studies have been carried out in various ways, at different scales, integrating various ranges of species and stages of the supply chain. Understanding them allows us to develop our own methodology based on our needs, taking advantage of the insights from each of them.

3.2.1 National scale

3.2.1 A. Bycatch

Bycatch from Fisheries

The report "Restitution of ObsMer Data for Professionals - 2020 Data" provides interesting insights (Cloatre Thomas et al., 2022). In France, data collection on fish catches began in 2002 with onboard sampling aboard Norway lobster fishing vessels in the Bay of Biscay. In 2003, onboard observation was expanded to cover all species and coastal regions. Subsequently, new regulatory requirements emerged, particularly for marine mammals, deep-sea fisheries, and tuna.

In 2009, onboard observation gained new momentum with the implementation of a revised version of the European Data Collection Framework (DCF) and the launch of the government's plan for sustainable and responsible fishing (PPDR).

The Directorate General for Maritime Affairs, Fisheries, and Aquaculture (**DGAMPA - EMFAF**) initiated the **ObsMer program**, co-financed by the European Union as part of the Common Fisheries Policy. This observation programme monitors both landed and discarded catches to better understand the interactions between fishing activities and marine resources and ecosystems. Observers are deployed on professional fishing vessels to document catches and fishing conditions. Each year, several dozen observers are employed by service providers contracted by DGAMPA. They are trained in sampling protocols, data entry tools by Ifremer (the French Research Institute for Exploitation of the Sea), and identifying species of fish, birds, and marine mammals by the National Museum of Natural History (MNHN) and the Pelagis Observatory. The ObsMer program is based on sampling theory. It is not feasible to observe all catches from all fishing vessels; instead, a random sample is selected to represent fishing activities as accurately as possible. The catches from this sample are observed in detail, and the results are extrapolated to estimate catches for all fishing vessels. However, this approach is not without errors due to weather conditions, spatial and temporal constraints on onboard work, difficulties in species identification, or inaccurate weighing in rough seas. Additionally, the sample may not always fully represent fishing activity, for instance, if certain seasons are not observed. Consequently, onboard observation data and the resulting estimates may contain errors or offer only a partial view of reality.

Since 2017, DGAMPA has consolidated the ObsMer and ObsVentes programs (sampling of landings at markets and specific landing points, meeting the requirements of the national work plan for data collection linked to the EU-MAP regulation). Access to this data requires prior approval from DGAMPA. Any data request must be submitted via the centralized SIH data access process. A request made in March 2024 through an online form has yet to receive a response.

At national level, data is collected by **FranceAgriMer**, the national establishment for agricultural and marine products, which serves as a hub for information, strategic discussions, decision-making, and management for French agricultural and fishing industries. Since 2013, FranceAgriMer has facilitated information exchange with stakeholders by offering e-services (online procedures) for various actions, such as online declarations. In the fishing sector, the VisioCapture service allows shipowners and captains to report catches and landings from vessels under 12 meters after registering on the portal. In 2017, France adopted a bioeconomy development strategy to sustainably meet its food and non-food needs. This strategy was operationalized through an action plan that includes comprehensive assessments of bioeconomy components to inform the National Biomass Resources Observatory (ONRB), established by FranceAgriMer, and to identify opportunities for developing new biomass valorization sectors. FranceAgriMer provides operators with economic analysis data for various sectors through the **VISIONet platform**. This website allows users to consult and download different types of data on production (including seafood) and access interactive datasets. For example, declared sales data from fish auctions in 2023 (FranceAgrimer 2024 - BIL-MER-VENTES-HAM-A23) indicate that the total quantity put up for sale was 152 695 tons, with unsold quantities amounting to 686 tons, or 0,045 %. Scallops accounted for 57% of the unsold volume.

In 2024 (from January to October), the total quantity of seafood put up for sale in fish auctions was 124 285,7 tons (Figure 7).

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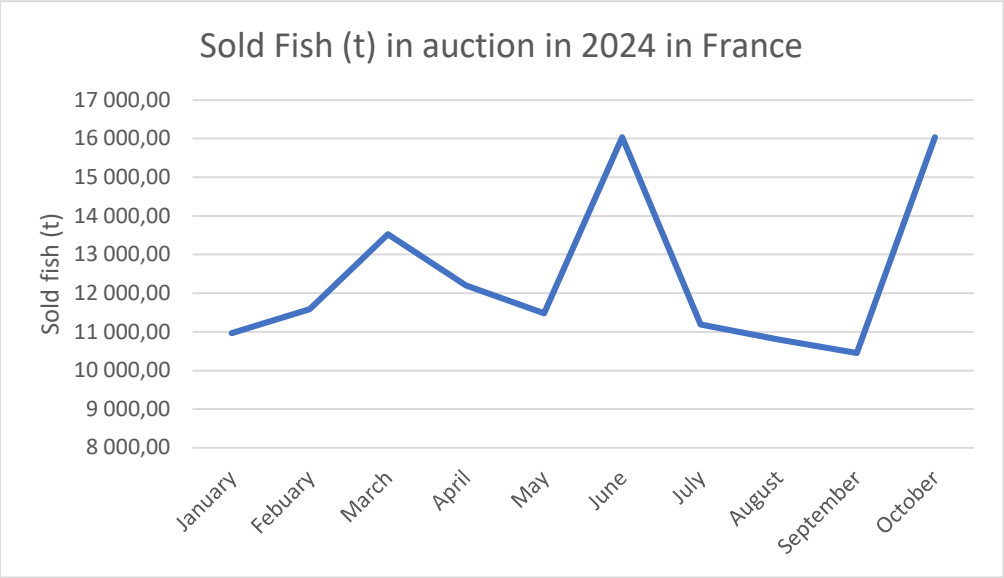

***Figure 7**: Monthly quantity (tons) of fish sold at auctions from January to October 2024 in France.*

A variable quantity of seafood sold at auction is observed depending on the month. This variability can be explained by several factors, such as the seasonality of certain species or the closure of fishing zones.

The VISIONet platform also provides data on unsold quantities from fish auctions in France for 2024 (from January to October) (Figure 8). The unsold seafood amounts to 171,6 tons from January to October. Additionally, sales outside of auctions totalled 83 439,61 tons.

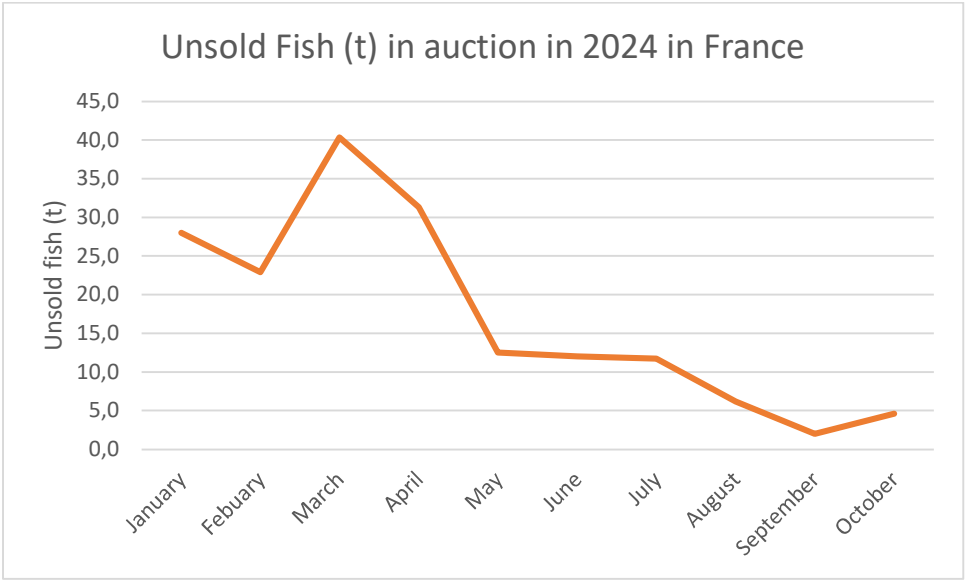

***Figure 8:** Monthly quantity (tons) of unsold fish in all French auctions from January to October 2024.*

From January to October 2024, the average monthly unsold quantity from fish auctions in France was approximately 17 tons.

While these unsold items from auctions could potentially be valorized, the data show significant month-to-month variation. This inconsistency complicates the efficient use of the resource. It is worth noting that the highest monthly volume of unsold products in 2024 was recorded in March, with 40,4 tons.

Bycatch, which refers to catches not intended for human consumption, is crucial for marine ecosystems. By being consumed by other species, bycatch contributes to ecosystem balance. The quantity of bycatch varies significantly depending on the fishing method, ranging from 3% to as much as 40% of the total catch in some fisheries. In Europe, since 2019, the European Commission has mandated "cleaner" methods through regulations requiring the return of bycatch that can be used for animal nutrition. These rules apply only to species managed at the European level under quotas or minimum size requirements. Through this landing obligation, the European Commission aimed primarily to encourage fishers to reduce bycatch to prevent population depletion. In practice, commercial species are typically retained onboard, while bycatch is often discarded at sea. Limited storage space on fishing vessels is reserved for target species due to their higher market value. However, at the end of a fishing trip, if there is enough room onboard, some bycatch may be retained for onboard consumption or as "godaille" (a portion of the catch left for the crew's personal consumption) (Steven Constant, 2023).

In mainland France, more than 300 species (fish, crustaceans, mollusks) are landed and marketed. A large majority are landed in small quantities, with approximately 50 species accounting for 95% of total landings (Alain Biseau (RBE), janvier 2023).

Selecting only the desired fish is a challenging task for fishermen due to the limited selectivity of fishing gear and the coexistence of many species in the same areas at the same times of the year.

To date, no precise data on the volume of bycatch in France has been found or obtained.

Bycatch from Aquaculture

In France, the quantity of bycatch from aquaculture and undesirable species is too insignificant and inconsistent to be subject to mandatory reporting or recorded by companies. At the same time, only a few companies have implemented integrated multi-trophic aquaculture (IMTA) systems on a pilot scale. As a result, no IMTA system is currently sufficiently developed to assess the quantity of biomass available from secondary species (or in a co-culture system) that are not yet commercially exploited (e.g., sea cucumber). Consequently, no data are available on the volume of aquaculture bycatch in France.

3.2.1 B. Marine by-products

For the **national scale**, all the data comes from a 2021 FranceAgriMer study presenting the total biomass of by-products in France in 2018. In this study, a mixed methodology was used.

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It combined indirect and direct methods, using data analysis and existing bibliography coupled with interviews on specific issues (estimation of unsold products in particular).

Marine by-products from Aquaculture

Quantifying the by-products generated from aquaculture in France is a developing area of research, but comprehensive national figures are still limited. However, on the Visionet platform of FranceAgriMer, a global estimation of **by-product** volumes in 2018 from the **processing** of species from **aquaculture** were found at national level as shown in Figure 9. Indeed, regarding aquaculture, and based on knowledge of by-product ratios, the ONRB tracks the volumes from the primary processing of farmed trout, as well as those from the smoking of farmed salmon and trout.

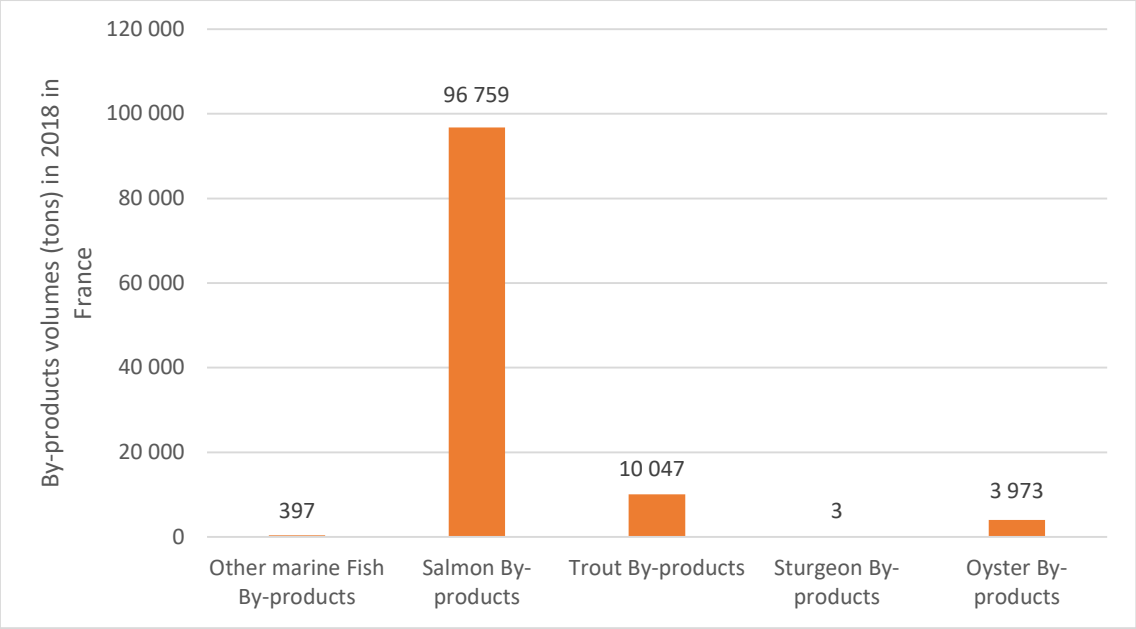

***Figure 9**: By-products volumes (tons) from Aquaculture France – in 2018.*

A significantly larger quantity of by-products is generated from salmon aquaculture compared to other species. Salmon by-products account for 87% of the total aquaculture by-products. In 2018, the total quantity of by-products from aquaculture reached 111 179 tons.

No additional data on marine by-products from aquaculture were available. While the volume of by-products such as shells is better documented, these are not included in this project.

Marine by-products from seafood processing industries

The most recent data available on the FranceAgriMer Visionet platform report the quantity of marine by-products in France for 2018. The results are presented in Table 1 below, sorted from the largest to the smallest quantity. It should be noted that there is a category labelled "fish," which likely represents all other species without commercial value. The total quantity of by-products from commercially valuable species (excluding the "fish" category) was 90 149 tons in France in 2018.

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By-products sources	Tons
Various Fish	150 000
Cod	67 844
Tuna	4 323
Mackerel	3 673
Haddock and herring	3 342
Sardines	2 082
Oysters	1 990
Hake, ling and whiting	1 781
Rays	1 518
Scallops	1 296
Dogfish	889
Anglerfish	787
Common hake	265
Cuttlefish	237
Anchovies	97
Spider crabs	25
Total	**240 149**

***Table 1**: Volumes (in tons) of co-products generated in 2018 for several species.*

In 2024, FranceAgriMer aimed to generate nation-wide by-product data by using the conversion coefficients published in the 2021 based on a 2018 study commissioned to three consulting firms. However, numerous inconsistencies were identified during the application of these coefficients. As a result, FranceAgriMer commissioned a new consulting firm to verify and, if necessary, correct the errors in their 2021 report for an updated version.

The new coefficients used in the current report were provided by FranceAgriMer to facilitate the Aquafish project French data. The updated conversion coefficients have been applied to 2018 data at the regional scale. This methodology could be replicated at the national level using input data on 2023 France landed volumes by species (or 2024 when the data becomes available).

In the future, France AgriMer objective is to annually update data on the volumes of marine by-products at the national scale.

Seaweed

French seaweed producers can fish, harvest, gather, or cultivate seaweed for various purposes, including direct or indirect human consumption (e.g., dietary supplements), agriculture (animal feed, soil amendments, and biostimulants), cosmetics and personal care, as well as the pharmaceutical industry. These activities involve varying levels of processing, from simple drying to the extraction of valuable molecules.

This extensive knowledge of seaweed species, their properties, and valorization techniques at different stages of exploitation stems from a combination of ancestral know-how and robust scientific expertise, supported by a strong territorial and cultural connection.

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Thanks to this advantage, France positions itself as the leading seaweed producer in the European Union, with an annual production volume ranging between 60 000 and 70 000 tons, consisting almost exclusively of macroalgae (French Government, 2024). In 2020, France ranked seventh worldwide among marine algae-producing countries, according to the FAO.

The harvest of seaweeds involves two brown algae species: *Laminaria digitata* and *Laminaria hyperborea*, with *Laminaria digitata* the predominant species. This activity is primarily carried out in Brittany by approximately thirty boats, known as *goémoniers*, using special equipment such as the "scoubidou" and the Norwegian rake.

Harvested seaweeds represent the largest volumes of seaweed produced in France, ranging from 50 000 to 70 000 tons of fresh weight annually (see Figure 10) (Feuille de route Algue, 2024). These seaweeds are primarily used to produce alginates, polysaccharides employed in various industries such as cosmetics, food and healthcare, for their thickening, texturizing, and gelling properties.

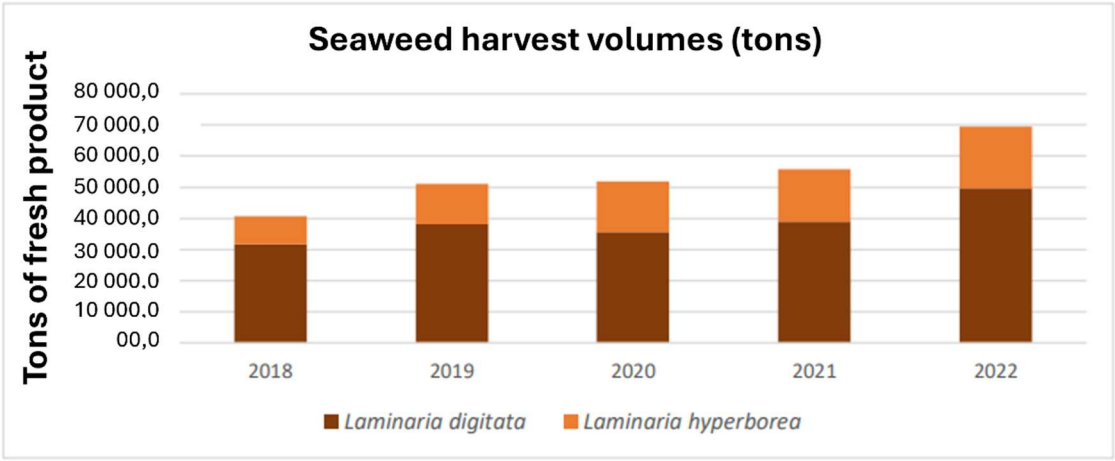

***Figure 10**: Volume (tons) of Laminaria digitata and Laminaria hyperborea harvested in France between 2018 and 2022.*

3.2.2 Regional scale: estimation of biomass volume in Brittany

3.2.2 A. Bycatch

Bycatch from Fisheries

Regarding fisheries, despite the ban on discards (or the landing obligation) in effect for all quota species and all European vessels since January 1st 2019, this regulation is rarely enforced in practice in France. As a result, it is not possible to evaluate bycatch in Brittany (European Parliament and Council of the European Union, 2013; French Fisheries Association, 2018). No data is available.

Bycatch from Aquaculture

For the same reason as at national level, no data were available on marine bycatch produced in aquaculture at the regional level.

3.2.2 B. Marine By-products

Marine by-products from Aquaculture

At regional level, no data were available on marine by-products produced.

Marine by-products from Auctions and Fish processing industry

Concerning the **regional scale**, the indirect methodology was chosen, considering the time and human resources allocated to this study. The advantage of this method is that it is far less time-consuming, since it does not require us to meet with as many players as possible, and that it provides a better overview of major trends, with more exhaustive and objective data. It does, however, require access to more precise data from different sources to perform the calculations.

We focused on Brittany because of its importance in the seafood industry. We also tried to consider French Cornwall (Cornouaille), but less data is available under this territorial scope.

Only seafood products landed in Brittany are considered in this study (both from fishing and aquaculture). Seafood products from other countries or regions but processed in Brittany will not be considered. Unlike at national scale, it is in fact impossible to characterize seafood import/export flows (import or export before processing) on a regional scale (FranceAgriMer, 2021). It is also impossible to estimate inter-regional flows. Nevertheless, considering that imports far outweigh exports in France and thus Brittany, the estimated volume of by-products will likely be underestimated. This will be especially significant for species like salmon or shrimp, where France is highly dependent on imports.

For the regional scale, the data used comes from various sources:

- Production:
  - Fishing: SACROIS 2022 data from the SIH (regional data sheet available on the Ifremer website, listing the top fifteen species by value per region) (Ifremer, 2024),
  - Shellfish farming (and more specifically mussel farming): 2022 data from the latest Agreste Aquaculture survey (March 2024),
  - Marine fish farming: CIPA data *(but very limited/scarce data available on the Internet),*
  - Algae: 2021 data from CRPMEM Bretagne (Regional Committee for Maritime Fisheries and Marine Farming).
- Processing rates:
  - Data indicated on FranceAgriMer (FAM) by-products report in 2021 with updates,
  - Data from interviews with professionals,

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- Data from the FAM report (2023) on "Consumption of fishery and aquaculture products - 2022" (proportion in quantities sold).

- Conversion coefficients:
  - Data from FAM by-products report in 2021 with updates,
  - Data taken from Andrieux (2004) report on "The French fisheries and aquaculture by-products sector: current situation and analysis",
  - Data from interviews with professionals.

The Figure 11 (below) illustrates the method used for each species (except algae): based on the tonnage landed on the territory, the volume going to processing and conversion coefficients specific to each by-product throughout various processes, the tonnage of each species and then the overall tonnage of by-products are obtained.

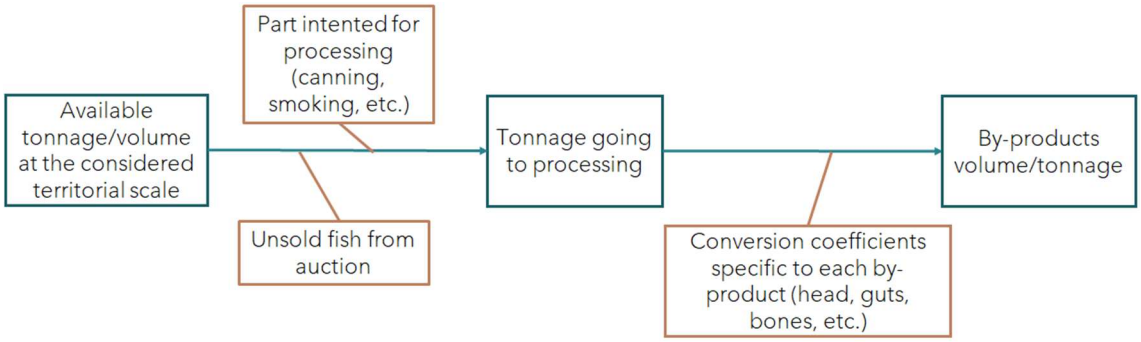

***Figure 11**: Graphic representation of the coproducts volume estimation method used (Master Thesis, Lise 2024).*

For macroalgae, since the entire product is considered, the method for estimating biomass is direct. The data is obtained directly through literature reviews or from stakeholders in the industry.

In analysing fishing by-products in Brittany, we initially sought to consider the top fifteen species landed by value in 2022 in Brittany, according to SACROIS data from the Fisheries Information System (SIH) (Ifremer, 2024). These species accounted for 48% of the total landed tonnage in Brittany. Among them, the material flow of eight species was examined in the FranceAgriMer (FAM) report, which served as the methodological basis for our study (FranceAgriMer et al., 2021a; FranceAgriMer et al., 2021b). These species include monkfish, tunas (yellowfin, skipjack), scallops, European hake, sardines, spider crabs, cuttlefish, and cod. Thus, these species were included in our estimation. For aquaculture, only mussels were analysed.

Table 2 below shows the landed tonnage evolution in Brittany between 2022 and 2023 for 16 species.

Species	2022		2023		% variation between 2022 and 2023
	Tonnage landed in Brittany	%	Tonnage landed in Brittany	%	
Monkfish	12 281	5	11 060	5	-9,94
Yellofin tuna	26 279	10	20 542	9	-21,83
Atlantic scallops	13 717	5	13 444	6	-1,99
Bonito	30 407	11	26 533	11	-12,74
Langoustines	2 008	1	1 902	1	-5,28
European Hake	5 136	2	4 670	2	-9,07
Little tunny	/	/	1 492	1	
Spider crabs	6 044	2	6 898	3	14,13
Common Sole	813	0	760	0	-6,52
Octopus	3 112	1	2 189	1	-29,66
Common sardine	18 470	7	15 146	6	-18,00
John Dory (Zeus)	949	0	903	0	-4,85
Sea bass	745	0	764	0	2,55
Calamari, Squid	1 271	0	/	/	
Cod	4 638	2	4 249	2	-8,39
Cuttlefish	2 384	1	2 900	1	21,64
Other species	139 735	52	120 535	52	-13,74
Total (all species)	**267 989**	**100**	**233 987**	**100**	

***Table 2**: Landed tonnage evolution in Brittany between 2022 and 2023 for 16 species*

The indirect methodology employed required us to evaluate the tonnage per species. Numerous assumptions were necessary to calculate by-products throughout the product flow. These assumptions come from the FranceAgriMer 2021 report.

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Species-specific data sheets were deemed the most concise way to present the information. Each sheet includes contextual information about the species or group of species: scientific and common names, landed or produced tonnage in Brittany (SACROIS 2022 data from Ifremer, 2024; Agreste 2022 data, Agreste 2024), main fishing regions, trade balance (2022 data from FranceAgriMer, 2024), and preferred consumption in France (FranceAgriMer et al., 2021b; FranceAgriMer, 2023c). Assumptions and their implications for calculations are subsequently detailed. A flowchart, modelled on the referenced FAM report and created using sankeymatic.com (Bogart, 2024), is included. The calculations are then outlined in detail. Information on market outlets, if available, complements the sheet. Only four species sheets (codfish, common sardines, tuna and mussels) are presented here; the remaining species were calculated similarly and are synthesised in the following Table 3 to avoid overloading the document.

We can see from the table below that the quantity of by-products generated for these species amounts to **62 937,56 tons** in 2022**.**

Types	Species	Production in 2022 (tons)	By-products (tons)	Percentage of by-product
Residues of fish from processing + unsold fish from auctions	Monkfish	12 281	9 210,75	75%
	Atlantic scallops	13 717	7 108,83	51,82%
	European hake	5 316	2 714,85	51%
	Codfish	4 638	2 852	61,5%
	Common sardine	18 470	3 878,33	21%
	Cuttlefish	2 384	1 013,20	42,5%
	Tuna (yellowfin tuna, bonito)	56 686	27 430	48,39%
Mollusks, shellfish, crustaceans (whole or part) discarded	Spider crabs	6 044	403,6 (with 59 tons of meat and 334,55 tons of body and shells)	6,6%
	Subtotal (fisheries)	**119 536 (over 498 320)**	**54 611,56**	
Mollusks, shellfish, crustaceans (whole or part) discarded	Mussels	24 978	8 326*	25%
	Total (fisheries + aquaculture)	**144 515**	**62 937,56**	

***Table 3**: Summary table of all estimates for considered species in Brittany in 2022.*

** Breton tonnage that would have been produced in 2022 based on 24 978 tons sold (Agreste, 2024).*

Algae were also considered in this report – see further below.

Codfish (*Gadus morhua*)

Latin Name(s): *Gadus morhua*
Other Common Name(s): Cod
Landed Tonnage in Brittany: 4 638 tons
Main Fishing Region(s): Brittany
Trade Balance: Imports exceed exports → -66 015 tons, equating to - 476 581 k€
Consumption: Preferably fresh, followed by frozen (with a small proportion as dried salted cod, i.e., "salt cod").

Tonnage landed in Brittany: 4 638 tons (Ifremer, 2024)

A small portion of codfish are gutted and beheaded on board. However, the exact proportion of codfish gutted and beheaded at sea is unknown. Therefore, we will assume that the 4 638 tons of fish are all landed whole and subsequently gutted and beheaded onshore. In 2022, there were no unsold codfish in Brittany (official auction data).

To calculate the quantities of viscera, heads, skins, and trimmings removed from whole fish, conversion coefficients from the updated 2021 FAM report (set to be published in early 2025) are applied (Table 4). The following table of assumptions will then enable the creation of a flowchart for this species.

Operation(s)	Conversion Coefficient(s)	Calculation	Result(s)
Gutting	1 kg of whole fish yields 0,855 kg of eviscerated fish, i.e., 0,145 kg of viscera.	4 638 x 0,145 = 672,5 tons	Product: 2 690 tons of eviscerated and beheaded fish
Beheading	1 kg of whole fish yields 0,725 kg of beheaded fish, i.e., 0,275 kg of heads.	4 638 x 0,275 = 1 275,45 tons	By-products: • Viscera: 672,5 tons • Heads: 1 275,5 tons

Table 4: *Calculation of the quantities of viscera and heads for Codfish in 2022, using the conversion coefficient*

All eviscerated and beheaded fish (2 690 tons), then go through a skinning and filleting stage (table 5).

Operation(s)	Conversion coefficient(s)	Calculation	Result(s)
Skinning	1 kg of whole fish yields 0,970 kg of skinned fish, i.e., 0,030 kg of skin.	4 638 (whole fish) x 0,03 = 139 tons	Product: 2 551 tons of eviscerated, headless, and skinned fish. By-products: 139 tons of skin.
Filleting	1 kg of whole fish yields 0,385 kg of fillets	4 638 (whole fish) x 0,385 = 1 785 tons	Product: 1 786 tons of fillets.

			By-products: 765 tons of flesh and bone scraps

Table 5: Calculation of the quantities of skin and fillet for Codfish in 2022, using the conversion coefficient

Using the table of assumptions and the calculations performed, a flowchart for this species can be created (Figure 12), highlighting the quantity of by-products generated at each stage.

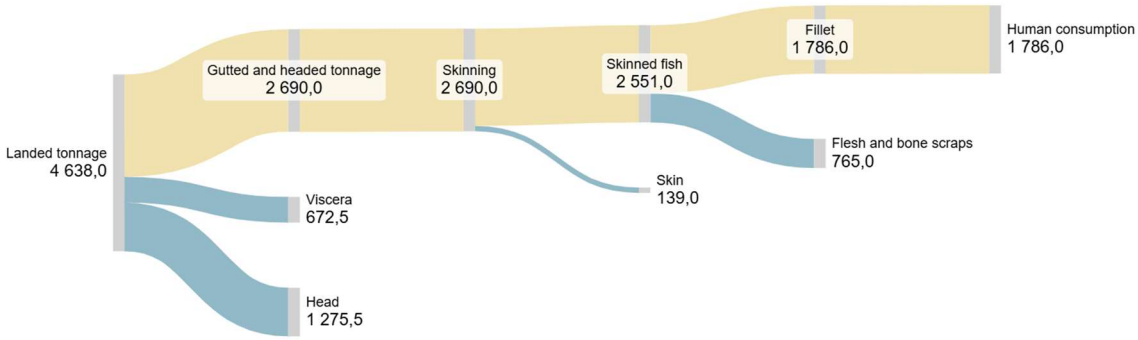

***Figure 12**: Flowchart of codfish raw material in 2022.*

The estimated total volume of codfish by-products generated from processing in Brittany in 2022, taking into account the absence of unsold fish, **amounts to 2 852 tons**, distributed as follows:

- 672,5 tons of viscera
- 1 275,5 tons of heads
- 139 tons of skin
- 765 tons of trimmings

This final tonnage of by-products, available for valorization, is likely overestimated as it does not account for by-products generated during on-board gutting and head removal, which are directly discarded at sea and not landed.

Uses of By-products

At the national level, these by-products are primarily used for animal feed (both livestock and pet food), bait production, as well as cosmetics and medical applications (FranceAgriMer et al., 2021b). A significant portion, however, remains unvalorized to this day.

Common sardine (*Sardina pilchardus*)

Latin Name(s): *Sardina pilchardus*
Other Vernacular Name(s): /
Tonnage Landed in Brittany: 18 470 tons
Main Fishing Regions: Corsica, Brittany
Trade Balance: Imports > Exports → -21 221 tons for -€80,011 million
Consumption: Mainly canned, partially fresh

Tonnage landed in Brittany: 18 470 tons (Ifremer, 2024)

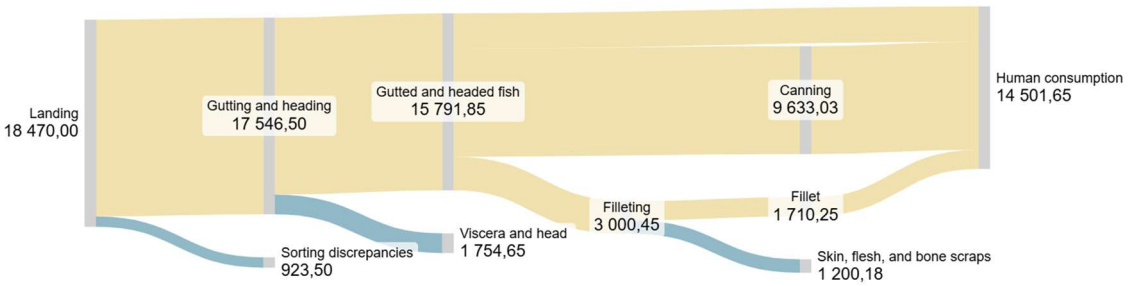

Figure 13: *Flowchart of common sardines raw material in 2022.*

In 2022, there were 0,2 tons of unsold fish for common sardines (according to official auction data). However, this data is not accounted for. Indeed, these volumes may be subject to contracts reintegrating them into various marketing channels, the quantification of which is currently unavailable.

Following landing, sorting is conducted with approximately 5% sorting discrepancies. 17 542 tons of sorted fresh sardines are obtained along with 923 tons of discarded sardines (sorting discrepancies), according to Figure 13.

Then, the selected sardines undergo a gutting and beheading stage (Table 6).

Operation(s)	Conversion coefficient(s)	Result(s)
Gutting and beheading	1 kg of whole fish yields **0,900 kg** of eviscerated and headless fish, i.e., 0,100 kg of viscera and head.	Product: 15 791,85 tons of eviscerated and headless fish. By-products: 1 754,65 tons.

Table 6: Calculation of the quantities of skin and filet for common sardines in 2022, using the conversion coefficient.

The distribution of eviscerated and headless sardines' volumes according to the final product regarding the modes of commercialization would be as follows:

- 61%: canned whole fish (9 633,03 tons) for human consumption
- 20%: whole fish (3 158,37 tons) for human consumption
- 19%: filleting (3 000,45 tons)

The quantity of fillets for Common sardines in 1 710,25 tons (Table 7)

Operation(s)	Conversion coefficient(s)	Result(s)
Filleting	1 kg of whole fish yields **0,570 kg** of fillet.	Fillets: 1 710,25 tons. By-products: 1 200,18 tons.

Table 7: Calculation of the quantity of fillet for common sardines in 2022, using the conversion coefficient.

The estimated total volume of sardine by-products from processing in Brittany in 2022, accounting for the absence of unsold fish, **amounts to 3 878,33 tons**, distributed as follows:

- 923,50 tons of sorting discrepancies
- 1 754,65 tons of viscera and head
- 1 200,18 tons of skin, flesh and bone scraps

This final tonnage of by-products, available for valorization, is likely overestimated as it does not account for by-products generated during on-board gutting and deheading, which are directly discarded at sea and not landed.

Valorization of Sardine Processing By-Products

The FranceAgriMer study (FranceAgriMer et al., 2021b) indicates that the valorization pathways for sardine volumes will vary significantly depending on the strategy of each site and its geographic location. The intrinsic qualities of the product will play a key role in determining the chosen valorization pathways:

- **Sorting variations**: Products that are "too large to fit into cans" but remain entirely acceptable in terms of organoleptic and sanitary qualities.
- **Damaged products or those with poor defrosting**: These can negatively impact organoleptic quality.

For products discarded due to their size, valorization toward human consumption is prioritized. However, to achieve this, sorting must be carried out at the industrial site to comply with hygiene standards. If sorting discards are not deemed fit for human consumption, the preferred pathway for valorization is animal feed production, especially fishmeal and fish oil. Sardines' high protein content and polyunsaturated fatty acids make them an excellent resource for animal feed production.

Sardine by-products can be valorized in various ways, depending on the situation, impacting the economic aspects of by-product treatment:

- **Sorted sardine by-products** can be processed into dedicated products like sardine meal/oil or sardine hydrolysates.
- **Mixed sardine by-products** with those of other species can be used to produce fishmeal or hydrolysates.

Niche applications also exist, such as the use of sardine scales in biomaterials (e.g. scalite).

Sorting variations represent substantial volumes and a potentially valuable resource for human food and ingredient production. The high protein content and polyunsaturated fatty acids in sardines make them a highly sought-after raw material in aquaculture feed.

Improved optimization in the valorization of by-products and sorting variations could help meet the growing demand for high-quality marine protein sources for both human and animal consumption.

Tuna

Latin Names: *Thunnus albacares, Euthynnus pelamis, Sarda sarda*
Other Common Names: Yellowfin tuna; Skipjack tuna, Atlantic bonito
Landed Volume in Brittany: 56 686 tons, including 26 279 tons of yellowfin tuna and 30 407 tons of skipjack and bonito.
Trade Balance (for all tuna species including albacore, skipjack, bluefin, etc.): -95 249 tons, valued at -610 118 k€.

The landing volume in Brittany was 56 686 tons, including 26 279 tons of albacore tuna and 30 407 tons of bonitos (Ifremer, 2024). It is assumed that all gutting occurs onshore, although at least a portion is reportedly performed onboard fishing vessels (FranceAgriMer et al., 2021b, Table 47, p.145). Furthermore, all species are processed and utilized in the same way (source: FranceAgriMer Report). The conversion coefficients are considered identical across all species.

Of the 56 686 tons of landed tuna, 12% is sold whole, while 88% undergoes processing (totalling 49 883,7 tons) (*New data from FranceAgriMer*). All tuna going to processing is gutted (Table 8).

Operation(s)	Conversion coefficient(s)	Calculation	Result(s)
Gutting	1 kg of whole fish yields 0,88 kg of eviscerated fish, including 0,12 kg of gills and viscera.	49 883,7x0,12=5 986,04 tons	Product: 43 897,6 tons of eviscerated and headless fish By-products: 5 986,04 tons of gills and viscera

Table 8: *Calculation of the quantities of viscera for tuna in 2022, using the conversion coefficient.*

Then, 100% of gutted tuna undergoes several processing steps before sale (Table 9):

1. Beheading/filleting
2. Quartering/loining

Operation(s)	Conversion coefficient(s)	Result(s)
Beheading/filleting	1 kg of whole fish yields 0,55 kg of fillet, with 0,180 kg of head, 0,080 kg of bones, 0,070 kg of black meat, and 0,012 kg of tail.	Product: 24 143,68 tons of headless and eviscerated product By-products: • Head: 7 901,57 tons • Bones: 3 511,81 tons • Dark meat: 3 072,83 tons • Tail: 5 267,71 tons
Quartering/loining	0,07 kg of skin is obtained per kilo of whole fish	By-product (skin): 1 690,05 tons

Table 9: *Calculation of the quantities of head, fillet and skin for tuna in 2022, using the conversion coefficient.*

Using the table of assumptions and the calculations performed, a flowchart for this species can be created (Figure 14), highlighting the quantity of by-products generated at each stage (in blue colour).

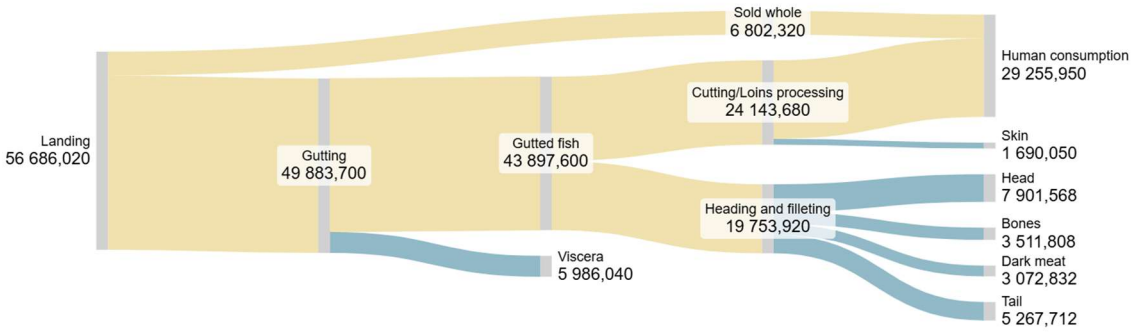

***Figure 14**: Flowchart of tuna raw material in 2022.*

The estimated total volume of tuna by-products generated from processing in Brittany in 2022, considering there were no unsold fish, **amounts to 27 430,05 tons**, distributed as follows:

- Gills and viscera: 5 686,04 tons
- Head: 7 901,57 tons
- Bones: 3 511,81 tons
- Dark meat: 3 072,83 tons
- Tail: 5 267,71 tons

Mussels

Latin Name(s): *Mytilus edulis*
Other Common Name(s): Common Mussel
Brittany Sales Tonnage (2022): 24 978 tons, including 16 478 tons in Northern Brittany and 8 500 tons in Southern Brittany
Trade Balance: Imports exceed exports → -47 867 tons, equating to -86 975k€
Consumption: Primarily fresh

For mussels, there is no available data on the volume of production in Brittany for 2022. However, the sales tonnage for Brittany is available. Based on this sales data, we can estimate the production volume.

Sales volume in Brittany (2022): 24 978 tons including 16 478 tons in North Brittany and 8 500 tons in South Brittany (Agreste, 2024). The mussels are primarily consumed fresh, reflecting their significant contribution to the local seafood market.

Breton mussels are exclusively sold whole. The only by-products considered are undersized mussels, which account for 25% of the marketed mussels.

I.e.:

- In North Brittany: 5 493 tons of undersized mussels out of 21 971 tons produced.
- In South Brittany: 2 833 tons of undersized mussels out of 11 333 tons produced.

Total mussels by-products: 8 326 tons.

Uses of by-product

These by-products represent a significant challenge for the sector as they represent approximately a quarter of the total production. Currently, several projects are being developed in Brittany to enhance their value, according to a mussel farming expert interviewed in 2024. These projects aim to use the by-products for human and animal food (e.g. aquafeed) or in agriculture (e.g. methanization). Some projects have been undertaken in the past but did not come to fruition.

Among the promising initiatives is the Méthacoq project by Cultimer (PETR du Pays de St. Malo, 2024). This project proposes to methanize shellfish by-products (including undersized mussels) to produce biogas. The approach involves setting up individual units at each company, enabling diversification of revenue streams. With the protocol validated, implementation by associated producers is expected by 2025.

The producer association Mussela is working to valorize these by-products for the agri-food industry (e.g. shelled mussels) and for aromatic and nutraceutical applications (e.g. concentrated cooking juices) (Région Bretagne, 2024). Another initiative, led by Mytilimer with the Kerbone project (SemBreizh, 2023), seeks to use mussel meat for human and animal food while processing shell powder as an eco-material.

Seaweed

For seaweed, the total biomass of macroalgae is considered. Within the framework of the Aquafish European project, an unified definition was adopted. While this is not the case in France, some partner countries classify the entire seaweed as a by-product or secondary species.

In France, macroalgae production still heavily depends on the harvesting of natural seaweed. According to Le Bras et al. (2014), French production fluctuates between 40 000 and 70 000 tons of fresh seaweed annually. In 2021, production reached 86 000 tons (FranceAgriMer, 2024b). Of this, 65% is harvested by seaweed boats targeting *Laminaria digitata* and *Laminaria hyperborea*, exclusively fished in Brittany (FranceAgriMer et al., 2021c; FranceAgriMer, 2024b). The remainder comes from shore-harvested seaweed (primarily in Brittany), washed-ashore seaweed collection (mainly in Nouvelle-Aquitaine and Brittany), and seaweed farming on lines (mostly in Brittany), primarily cultivating *Undaria pinnatifida* and *Saccharina latissima*.

In Brittany, the CRPMEM estimates the 2021 production at 73 400 tons of fresh wet weight (2022), including:

- 6 436 tons (Figure 15) from manual harvesting of shoreline seaweed in 2021 (around 5 000 tons annually):
    - Over three-quarters are from two species/groups: 46% *Ascophyllum nodosum* and 36% *Fucus* spp. (CRPMEM Bretagne, 2023).

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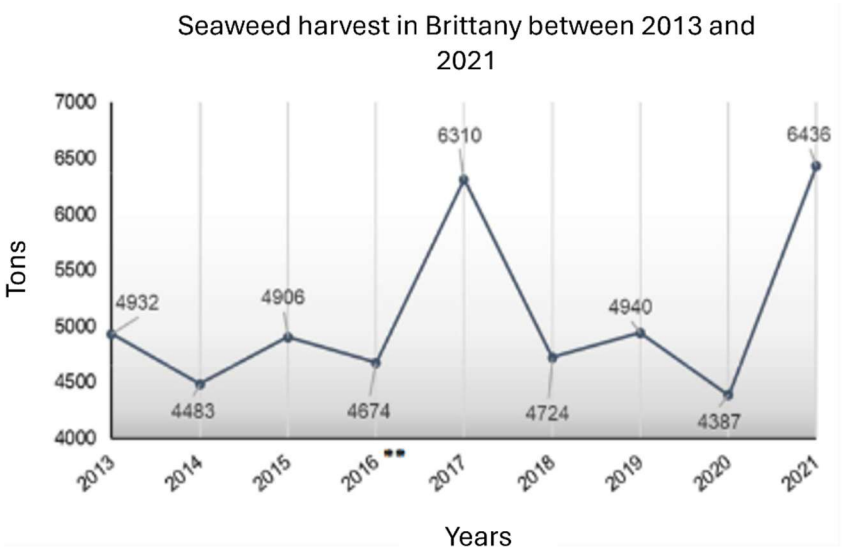

***Figure 15**: Evolution of algae harvesting collection in Brittany from 2013 to 2021, based on monthly declarative data provided to the Brittany DDTM DMLs. ** Incomplete 2016 data (November and December data not captured). (Source: CRPMEM, 2023).*

- 66 904 tons harvested by boat in 2021 (approximately 60 000 tons annually).
- A marginal portion from seaweed farming:

  This involved approximately 12 companies in Brittany (2020), producing an unknown quantity but less than the 290 tons produced nationally in 2022 (Agreste, 2024).

Uses of Macroalgae

Macroalgae are utilized across various sectors: agriculture (soil amendments, biostimulants, etc.), human and animal nutrition, cosmetics, and pharmaceuticals (FranceAgriMer et al., 2021b; expert consulted, 2024). Numerous businesses in Brittany, the leading French region for seaweed, process seaweed for human consumption. Products include spreads, ingredients for the agri-food industry, and alternatives to animal protein sources (FranceAgriMer, 2024b). Additionally, the CEVA (Centre for Study and Utilization of Algae) supports this activity.

Seaweed By-Products

A few projects in France aim to valorize seaweed by-products. One example is the Agriplast project (conducted in Normandy), which seeks to develop materials and finished plastic products derived from seaweed by-products and derivatives (Marieux, 2022).

3.2.3 Cornouaille - French Cornwall

French Cornwall is a maritime region with seven fishing ports, six of which are equipped with auction markets. This Cornwall port complex plays a major role in the development and organization of the territory (Figure 16).

***Figure 16**: Map of the 7 Fishing and Leisure Ports (Source: SMPPC).*

Since January 1, 2018, the **Syndicat Mixte Ports de Pêches et Plaisance de Cornouaille (SMPPC)** has served as the sole point of contact for professionals and users of these ports. Its objectives are:

- To develop, maintain, and manage the ports;
- To integrate port activities into regional economic development and the local economic fabric;
- To incorporate port development into the city-port interface

The **Syndicat Mixte** has delegated the management of Cornwall's fishing ports to the **Finistère Chamber of Commerce and Industry - Quimper Delegation (CCI Quimper)** through a public service delegation.

Each of the seven Cornwall ports has its unique identity and specialties (source: Port de France). With its 7 fishing ports, 6 of which have auctions:

1. **Audierne**: The port of Audierne remains a key landing site for high-value species such as sea bass, bream, John Dory, pollock, red mullet, and sole. Nearly 67 buyers regularly purchase fish there, with 91% of volumes being traded via remote sales—a rapidly growing practice.
2. **Concarneau**: Concarneau is a stronghold of inshore fishing and is also recognized for its expertise in shipbuilding. This hub of excellence is unique along the Atlantic coast, with 55 companies and 1 000 jobs. The port generates 1 900 jobs, making it a major economic driver for the region.
3. **Douarnenez**: Since 2012, the Chamber of Commerce has invested in a comprehensive modernization and compliance program for the Douarnenez fish market. This initiative has strengthened the port's role as a landing and processing site for blue fish (sardines,

anchovies). Douarnenez is also a strategic base for deep-sea vessels, thanks to its western location and permanent water depth.

4. **Le Guilvinec**: With 19 000 tons of fish landed and sold annually, Guilvinec ranks as the second-largest auction market in France. It is the leading offshore fishing port in Cornouaille, hosting 37 offshore vessels and a substantial coastal fleet of 40 boats and about 15 small crafts. The port is a dynamic market for species like monkfish, langoustine, skate, and more.

5. **Loctudy**: Loctudy is renowned for its star product, langoustine, known as "*La Demoiselle de Loctudy*" – Loctudy's lady. Offshore fishing accounts for 85% of the port's volumes and 80% of its value. The seafood trading activity here is highly dynamic, with 12 buyers operating next to the fish market, handling over 10% of the fish purchased in Cornouaille ports.

6. **St. Guénolé Penmarc'h**: Nestled among dangerous rock formations, the port of Saint-Guénolé aptly lives up to its reputation as "the challenge port". It is home to a significant fleet of trawlers, purse seiners (sardine boats), and small crafts for net, line, or pot fishing. Its hallmark is sardine fishing, making it the fifth-largest French fishing port by volume.

In 2023, the total landed volume in Cornwall was **42 154 tons**, a decrease of 12,57% compared to 2022 (-6 058 tons) (Syndicat Mixte Ports de Pêche et Plaisance de Cornouaille, 2023). Factors contributing to this decline included bad weather at the start of the year, strikes in March, and a weaker tuna season in both volume and price.

By the end of 2023, the Cornwall fleet comprised:

- 241 vessels under 12 meters-long;
- 62 vessels between 12 and 16 meters-long;
- 73 vessels between 16 and 25 meters-long;
- 18 vessels over 25 meters-long.

The number of sailors was **1 551**, representing 30% of Breton mariners.

To estimate the marine by-products in Cornwall (Table 10), we can apply the conversion coefficient provided by the FranceAgriMer report to the landed volumes in Cornwall.

In order to do this, however, we need to know the quantities of each species landed at Cornwall. Some of this information can be found in the Halles à Marées report by France Agrimer (FranceAgrimer 2024 - BIL-MER-VENTES-HAM-A23). In particular, it indicates the volume of fish sold for the 6 Cornwall auctions: 32,177 tonnes in 2022 (Table 10).

	Total Fish sold (tons)
Douarnenez	7 012
Loctudy	2 775
St Guénolé Penmarc'h	4 435
Le Guilvinec	13 187
Concarneau	3 615
Audierne	1 153
Total	32 177

Table 10: Total number of fish sold in Cornwall in 2022 (tons)

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This report on the sales balance sheets of French fish markets in 2023 provides detailed data for 2022 regarding sales at the main fish markets for various landed species. However, it is possible that a fish market in Cornwall also sold one of the species in question but was not included among the main markets, and therefore its figures are not reflected. As a result, the data are likely underestimated but still offer a general overview (Table 11).

Types	Species	Volumes of fish Sold in 2022 in Cornwall (tons)	By-products (tons)	Rate of by-products (from Britanny estimate)
Residues of fish from processing + unsold fish from auctions	Monkfish	5119	3 839,25	75%
	Atlantic scallops	0		
	European hake	1160	591,6	51%
	Codfish	70	43,05	61,5%
	Common sardine	10379	2 179,59	21%
	Cuttlefish	177	75,25	42,5%
	Tuna (yellowfin tuna, bonito)	36	17,42	48,39%
Mollusks, shellfish, crustaceans (whole or part) discarded	Spider crabs	14	0,924	6,6%
	Subtotal (fisheries)	**16 955**	**6 747,08**	

Table 11: Summary table of all estimates for considered species in Cornwall in 2022.

With estimated 6,747.08 tons of by-products generated in Cornwall out of the estimated 30,282 tons produced in Brittany, Cornwall accounts for 22% of Brittany's by-products.

3.3 Spain

The first point to clarify is that there is not a specific law or regulation for the management of bycatch or by-products in Spain. According to this, the control of these raw materials from fisheries and aquaculture industries must be done following **European regulations**. This way, there are two main regulations to consider: the Regulation (EU) No. 1380/2013 laying down the Common Fisheries Policy (CFP) about **bycatch** and the Regulation (EU) No. 1069/2009 laying down on health rules as regards animal **by-products** and derived products not intended for human consumption.

Fisheries

All the raw materials from the fishing fleet with the correct hygienic conditions (not too much time exposed to the sun or not contaminated by other ways like fishes that fall down to the floor etc) can be used for **direct human consumption**. Among all these raw materials from fisheries there is a part that is considered as discards, which cover the following catches: no target species, exceeded quotes and size below of the minimum established by the CFP. Discards must be landed from 2016, according to the **Regulation (EU) No. 1380/2013**. There are only a few

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exceptions that can be returned to the sea, such as prohibited or protected species, high survival rate species and *minimis* (a 5% of the total annual catches by species). Therefore, a limited part of **discards** (species caught accidentally) is returned to the sea (exceptions of 5% maximum), while another considerable amount must be landed according to the corresponding Regulation, which is known as **bycatch** (species caught accidentally and landed at dockside). It is crucial to highlight that **bycatch is taken into account for the capture quotes of the boat** (European Union, 2013).

Bycatch could have different applications depending on the reason why they were discarded. For example, the ones discarded because of the **minimum size or the exceeded quote** may not be destined for direct human consumption. Instead, they could be used for other applications (feed, pharmaceutic or textile industries) or even for **indirect human consumption** (Valeiras, 2015). It means they need a previous transformation process to be considered as an optimum food for consumers, such as **surimi** food.

On the other hand, when raw materials are discarded because they are not the **target species** of the boat, this does not mean that they cannot be used for **direct human consumption**. The main problem is that these raw materials are usually species with **low commercial value**, and they are not easily marketable. An alternative option is the **indirect human consumption** through a previous transformation process. A similar situation takes place with the bycatch in the case of **injuries or deformations**. They do not have value in the market by themselves, but they can be revalorized and turned into a new product by a transformation process.

Bycatch must be managed in a different way compared to raw material that is not bycatch (objective catch). They must be also separated from the rest of the raw material because their **final application could be different** to the objective catches, for instance if this material is not going directly to auctions or human consumption. Besides, the compilation of information about the process of management and a quantitative **estimation** of these bycatch should be done by each boat every fishing day to have a control of them. These data should be written on the **fishing notebook** and shared with the correspondent public entities, being the Ministry **of Agriculture, Fisheries and Food** in the case of Spain, concretely with the **General Sub-direction of Fishery Vigilance and Control against Illegal Fishing**.

All **objective catches are stored in the hold**, protected and classified by species. However, **bycatch is usually stored on the deck**, all together in piles without classification or separation. This difference of management between objective catches and bycatch is mainly due to the **lack of space** on the boats and the limited **time during working hours**. For these reasons, fishermen have to prioritize the storing of the objective catches, which will be commercialized for human consumption, and which present a higher commercial value. Moreover, bycatch is not positively evaluated by the consumers, and they have **low prices on the market**. The main causes could be due to unknown species, deformations, species without interest due to their own physical-organoleptic properties, etc. Besides, all the bycatch with low commercial value is probably destined for non-human consumption, such as fishmeal, which is commercialized at lower prices than the fish for human consumption in auctions or markets. Therefore, fishermen **prioritize the management of the objective catches**.

Then, all bycatch is stored together on the deck, in piles without classification, during the entire fishing day until they arrive at the port. This could compromise the **quality and safety of the bycatch** due to the exposure to the sun, the high temperatures, the exposure to other strange bodies, the accumulation of raw materials and effluent liquids, the possible contact among a polluted piece with the rest, etc. In addition, the objective catches are quickly unloaded when the boat arrives at the port, but probably not the bycatch. All these factors could affect the quality and safety of the bycatch and endanger their future consumption by animals (feed) or humans (indirect consumption by transformed products).

Because of the presumably bad storage conditions of the bycatch, they are **organoleptic and microbiologically validated** prior to their use for whatever application, to guarantee the quality of the product and the safety of the consumer. It is supposed that fishermen and the company that collects bycatch checks the quality of fishes. There is not a particular organism that does this task and there is not a register of this task at landing. It is supposed to be the final company who carry out the organoleptic and microbiological check.

The estimation of bycatch in the **fishing fleet** (only **quantitative amount**, without classification by species due to the lack of space and time as it was discussed above) is done by the workers of the boat. This data is written down on the fishing notebook. However, as they do not have the proper equipment to weigh the biomass, the correct estimation of bycatch is finally done (with the suitable equipment) by the **ABP (Animal By-Products not intended for human consumption) company employees** who manage the bycatch of the boat on the dock, destined for feed industry (European Union, 2009). This data is contrasted with the previous one and the final information is shared with the **Ministry of Agriculture, Fisheries and Food.** In contrast with the previous information, data of bycatch from fisheries are **public**. However, these data are not available anywhere and only belong to the corresponding Ministry.

With respect to the **fishing fleet**, **bycatch volume estimations per year at national level** were found through online searching. No official information at regional level was found. Presumably, more information should be available in the Ministry of Agriculture, Fisheries and Food databases. However, requests asking for these data were all ignored. Besides, some research **studies of estimation of bycatch at regional level (Cádiz)** were found.

Auction

The product that goes to most of the **auctions** is only the **objective catches**, it means, only the commercial raw materials. **Bycatch does not arrive at the auction**. Instead, it stays on the boat or on the dockside until they are sold, mainly to the feed industry. They could be also sold to seafood industry, pharmaceutical and cosmetic industry, investigation centres, etc., depending on the reason why they were discarded, as discussed previously.

In some cases, a part of the objective catches in auction remains **unsold**, and will thereby turn into **by-products**. These by-products, which are **objective species expected to be discarded** (in this case because they are unsold in auction), could be destined to any industry but since it is an occasional situation and the amount of them are not significant, they are usually **donated to food banks**.

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Therefore, there is **no estimation of by-products in auctions** because they appear only in occasional situations and in insignificant amounts, and therefore quantity estimation exists. Besides, these by-products go directly to food banks through donations. Then, no information at national or regional level is available anywhere because **these databases do not exist**, as mentioned before.

Aquaculture industries

Spanish aquaculture industries are focused on specific species cultivated in controlled and closed sea environments. Consequently, there are not many non-target species and when they are caught accidentally, they are not returned to the aquaculture systems, no matter the reason for their discard. For this reason, discards in aquaculture industries do not exist. Bycatch in aquaculture are represented by **secondary or undesirable species**, different to the objective one, that appear in the farm and are caught accidentally.

Moreover, some of the target **species** in the aquaculture industry are **not marketable** because of different reasons: size too small, deformations, strange colours and other anomalies. They are known as **by-products**, cultivated and objective species but not marketable. Both bycatch and by-products from aquaculture industries are destined to other industries for their exploitation, such as cosmetic, pharmaceutic, seafood processing or feed industry.

Aquaculture industries are private for-profit companies and the management and quantity of their bycatch and by-products are **private** issues. Since neither secondary or undesirable species (bycatch) or cultivated species not marketable (by-products) are of direct interest for the company, they probably store bycatch and by-products all together without separation or classification, destined for ABPs. There are situations in which aquaculture industries are related with seafood industries. In these cases, bycatch destined for ABPs are accumulated together as before whereas by-products (with anomalies) could be destined for the **seafood industry associated**.

With respect to **aquaculture industries**, the information about bycatch and by-products is **private**. Nevertheless, a very rough estimation at national and regional level of volumes of bycatch and by-products in the aquaculture industry was obtained through ABPs **companies**, who are responsible for the management of these bycatch and by-products from the industries.

Seafood processing industries

Seafood industry is responsible for the processing of raw materials from the fishing fleet, aquaculture industries or even fish auctions. The processing of fish and other marine products consists of a **transformation step** that allows for the preparation, conservation and labelling of the final products. The seafood processing could be primary processing, such as removing bones, head, guts, tails, etc. to obtain fillets or second processing to obtain a transformed product such as canneries, smokehouses, prepared foods, etc.

In all of these types of seafood processing industries there is a generation and accumulation of bio-wastes, e.g. parts of fishes, like **bones, tails, heads, skin, scales, guts and other parts**, which are known as **by-products**. These by-products are intended to be discarded and used for other purposes, such as the industries mentioned above, including their exploitation in the same

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industry who generated them through a new transformation process to obtain a **new high-value food product for human consumption** from by-products.

In the **seafood processing industry,** the information about how they classify their by-products and the amount of them is **private** because they are private companies for profit. Anyway, they probably classify their by-products according to the type of bio-waste, by kind of by-product or even by species if they process different species. Based on our own experience, seafood industries separate by-products according to the raw materials they are intending to use: by-products they want to **revalorise** are correctly separated by type of by-product and species, while those ones they are not interested in are piled up together without separation or classification.

The information about bycatch and by-products from **seafood processing industries** is **private**. Nevertheless, a very rough estimation at national and regional level of volumes of bycatch and by-products in the seafood industry was obtained through ABPs **companies**, who are responsible for the management of these bycatch and by-products from the industries.

Animal by-products

All bycatch and by-products from different origin (fishing fleet, aquaculture industry, auction and seafood industry) are apt for human consumption and can be destined for its purpose (except to raw materials discarded due to their minimum size or the exceeded quote of the boat but only by legal restrictions), either direct or indirectly (following a transformation process). On the other hand, there is a part of bycatch and by-products that is **not edible for human consumption**. This part includes raw materials that are **contaminated or rotten** because of a negligence manipulation, an inadequate conservation, contact with strange and external agents, etc.

Contaminated or rotten bycatch and by-products are categorized as ABP and they are preserved separately from the rest of raw materials with the correct storing conditions. The ABP is properly managed by an authorized entity and it is used for other applications different from human consumption, mainly for elaborate fishmeal for the feed **industry** (Iñarra et al., 2018).

However, the majority of bycatch and by-products from any moment of the value chain of the products (fishery, aquaculture, auction or seafood processing), contaminated or not, is classified at ABP. As a result, ABP management companies are in charge of handling the most of bycatch and by-products of this sector and almost everything from marine bycatch and by-products is used for the feed industry.

3.3.1 National scale

3.3.1 A. Bycatch

From Fisheries

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Figure 17 shows the **volumes of bycatch (in tons) per year at national level from Spanish fisheries**, for the last fifteen years (MAPA, 2023).

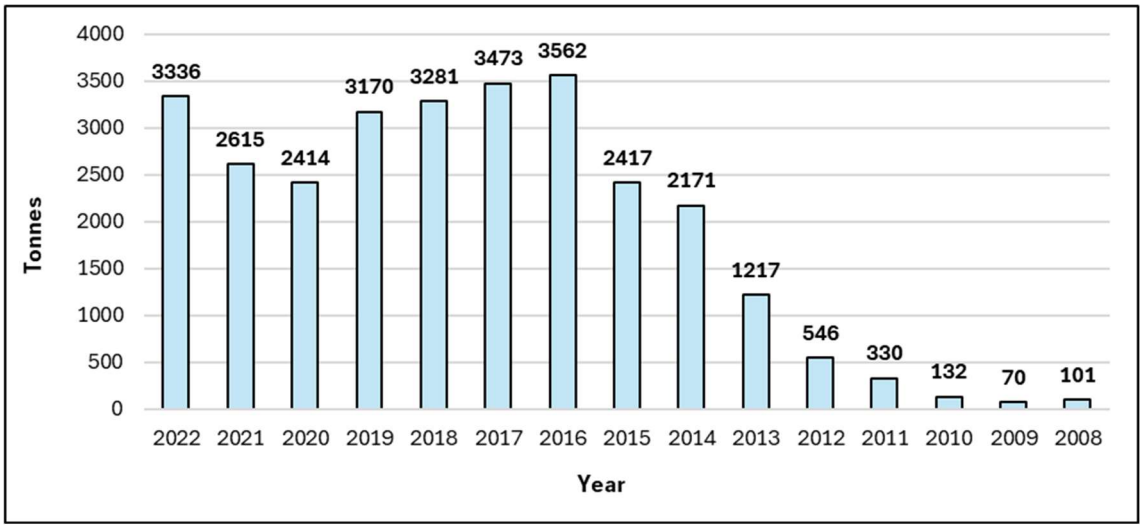

Figure 17: *Volumes of bycatch (in tons) per year at national level from Spanish fisheries, for the last fifteen years.*

Data reflect volumes of bycatch **up to 3 000 tons** (3 000 000 Kg) since 2016, excepting years 2021 and 2020, due to the crisis originated by the COVID-19 pandemic, in which volumes fell to around 2 500 tons of bycatch. It represents a huge amount of bycatch (species) that are not used for human consumption but mainly for animal consumption (feed) and other applications. It is essential to consider these enormous volumes of bycatch and their future use, considering the prediction of lack of food for everybody in the next decades.

The amount of bycatch progressively **decreased from 2015** to the previous years. It could be due probably to the lack of regulation in these years (landing regulation became effective in 2013), in which a big part of the bycatch was managed as discards and returned to the sea.

From Aquaculture and Seafood Processing Industries

As it was mentioned previously, most of the bycatch and by-products from fisheries and industries (aquaculture and seafood processing) are intended for ABP **companies**. Therefore, these ABP companies also have information about the amount of bycatch and by-products obtained in each sector (fisheries, aquaculture industries and seafood industries). Thereby, an **indirect estimation of volumes of bycatch and by-products from aquaculture and seafood industries** was obtained from an ABP company, concretely the most relevant company in the field at national level, who recovers and manages approximately the **50% of the total ABP in Spain**.

This company handles around **30 million of Kg of ABP per year at national level** from the marine-aquaculture sector, of which **18 million of kg belongs to Andalucía**. Both at national and at regional level, more than **95% of this bycatch and by-products destined for ABP are from seafood processing industries and markets**. Then, less than 5% of these volumes come from fisheries, auctions and aquaculture industries. Therefore, **seafood processing industries support the majority of the volumes of ABP (by-products) while aquaculture industries barely contributed**.

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These data only represent the 50% of bycatch and by-products and is an indirect estimation but they are a very real value of the actual situation about bycatch and by-products from the sector. Moreover, ABP companies are **private** too, so the rest of the data are confidential.

From auctions

No bycatch reaches auctions, only commercial species. The bycatch generated after the auctions business is very scarce and they are usually donated.

3.3.1 B. Marines By-products

According to Spanish by-products management, no by-products are generated from fisheries, aquaculture industries or auctions. Respect to seafood processing industries, the information related is confidential.

3.3.2 Regional scale

3.3.2 A. Bycatch

From Fisheries

There is not any database or official information about bycatch at regional scale. Instead, there are some investigation **studies of estimation of bycatch at regional level** (Cádiz, Andalusia). These studies were carried out by scientists on board the fishing fleet of Cádiz gulf, who observed and quantified the volumes of bycatch obtained. The number of catches and bycatch of each cast was **estimated** due to boats not using scales on many occasions.

The first study (Cabrera-Castro et al., 2020), between May 2019-November 2020, was carried out with the **fishing fleet of Sanlúcar (Cádiz)**, whose activities are focus on the Cádiz gulf and its port (Bonanza) is the second fishing port more important in Andalucía. It counts with a total of **127 boats** (52 of trawling boats, 60 of small techniques and 15 of purse seine boats). It was carried out a total of 10 boarding in trawling boats (with 3 casts per boarding) and 7 boarding in purse seine boats.

For **trawling boardings**, around 500-600 kg of catches per cast were obtained, of which **200-250 kg were bycatch (55-60%** generated by any reason**),** with a total amount estimation of bycatch of 600-750 kg per boarding. Taking as a representative quantity of bycatch **284,72 kg for the 10 boardings** (collect a part of each cast until a total of 284,72 kg), there were a total of **13 401 specimens**, divided in **173 different species**. Bycatch were constituted by 86,30% of vertebrate fish, 12,10% of invertebrates and 1,60% of elasmobranchs (according to the number of specimens). Taking into account only the vertebrate fish fraction (main), the 96,11% of them were commercial species, of which 43,7% consisted of only 4 species: horse mackerel (*Trachurus trachurus*) with 57,6 kg, scaldfish (*Arnoglosus* sp.) with 17,11 kg, anchovy (*Engraulis encrasicolus*) with 12,48 kg and brown comber (*Serranus hepatus*) with 11,17 kg. However, they were discarded as bycatch because of their small size. On the other hand, small-spotted catshark

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(*Scyliorhinus canicula*) with 17,86 kg and marbled electric ray (*Torpedo marmorata*) with 13,0 kg were the main species for elasmobranchs. The rest of the species were in minority. Regarding this study, the volume of bycatch per day for the trawling fleet of Sanlúcar is the following : 31 200-39 000 kg.

For invertebrates (12,10% of bycatch studied), 26 species of crustaceans, 24 of mollusks, 12 of echinoderms, 5 of cnidaria, 2 of annelids 1 of bryozoan, 1 of sponge and 1 of jellyfish were caught, with a total of 27,27 kg (9,58% according to weight). In crustaceans, the most representative species were *Plesionika heterocarpus* (5,15 kg), *Squilla mantis* (2,3 kg), *Liocarcinus depurator* (1,66 kg) and *Parapenaeus longirostris* (1,56 kg); in cephalopods, *Sepia elegans* (485 g) and *Eledone moschata* (502 g); in cnidaria, *Calliactis parasitica* (1,06 kg) and *Pteroides spinosum* (841 g); in mollusks, *Venus nux* (1,55 kg); in echinoderms, *Astropecten irregularis* (831 g), *Parastichopus regulis* (912 g) and *Nymphaster arenatus* (757 g).

According to **purse seine boardings**, only **14,75 kg** (**103 specimens divided in 3 species**) of bycatch were obtained **for the 7 boardings**, of which 8,99 kg was bogue (*Boops boops*), 3,88 kg was chub mackerel (*Scomber colias*) and 1,88 kg was annular seabream (*Diplodus annularis*). It should be mentioned the punctual catch of jellyfish (*Rizostoma lutheum*) in one boarding, with a total quantity of 14,2 kg. Regarding this case, the volume of 30 kg bycatch per day for all the Sanlúcar fleet is the following: 30 kg (a not significant quantity).

The second study (Cabrera-Castro et al., 2021), between August 2020-March 2021, was carried out with the **fishing fleet of Sanlúcar and the fishing fleet of El Puerto de Santa María**, both focusing on the Gulf of Cádiz. The fishing fleet of El Puerto de Santa María counts **29 boats** (17 trawling boats, 6 purse seine boats and 6 of other techniques). It was carried out a total of 6 boarding with the Sanlúcar fishing fleet (a total of 17 casts, with an average of 3 casts per boarding when the weather allowed it) and 5 ones with the El Puerto de Santa María fishing fleet (with 3 casts per boarding), all of them through trawling boats.

For the **Sanlúcar boardings**, 140-350 kg of catches were obtained by boarding, of which **50-117 kg (17-50%) were bycatch**. Considering as a representative quantity of bycatch **175,08 kg for the 6 boardings**, this fraction was constituted by **12 638 specimens**, divided in 88,9% of vertebrate fish, 11% of invertebrate fish and 0,2% of elasmobranchs (according to the number of specimens). Taking into account the higher fraction of bycatch (vertebrates), main species founded were Senegal seabream (*Diplodus bellotti)* with 21,12 kg, red pandora (*Pagellus bellotti)* with 15,68 kg, anchovy (*Engraulis encrasicolus*) with 11,14 kg, European pilchard (*Sardina pilchardus)* with 9,56 kg, gobies (*Lesuerigobius* sp.) with 9,36 kg and bastard grunt (*Pomadasys incisus*) with 9,1 kg. On the other hand, spot tail mantis shrimp (*Squilla mantis*) was the main species found for invertebrates with 10,1 kg. The rest of species were in minority. Regarding this study, the volume of bycatch per day for the trawling fleet of Sanlúcar is the following : 2 600 – 6 084 kg.

For invertebrates (11% of bycatch studied), a total of 28,45 kg were found (16% according to weight), classified as follow (only mentioned the most representatives species): 23 species of crustaceans (10,1 kg of *Squilla mantis*, 2,76 kg of *Medorippe lanata* and 1,88 kg of *Goneplax rhomboides*), 5 species of cephalopods (385,2 g of *Alloteuthis media* and 300,8 g of *Eledone mostacha*), 12 species of bivalves (680,8 g of *Anomia* sp. and 280,1 g of *Venux max*), 9 species

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of gastropods (3,54 kg of *Cymbium olla*), 5 species of echinoderms (3,44 kg of *Astropecten irregularis*), 5 species of cnidaria (196,42 g of *Calliactis parasítica*), 1 species of polyquats (36,75 g of *Sipunculus nudus*), species of tunicates (109,68 g of specimens of Salpidae family).

According to **El Puerto de Santa María boardings**, around 153 kg of catches were obtained by boarding, of which **74 kg (49%) were bycatch**. Considering as a representative quantity of bycatch **150,55 kg for the 5 boardings,** this fraction was constituted by **5 345 specimens**, divided in 78,9% of vertebrate fish, 20,9% of invertebrate fish and 0,2% of elasmobranchs (according to the number of specimens). Taking into account the higher fraction of bycatch (vertebrates), main species founded were anchovy (*Engraulis encrasicolus*) with 23,49 kg, horse mackerel (*Trachurus trachurus*) with 31,32 kg, bogue (*Boops boops*) with 12,72 kg and common pandora (*Pagellus erythrinus*) with 4,89 kg. On the other hand, sea grape (*Molgula* sp.) was the main species found for invertebrates with 24,69 kg. The rest of the species were minority. Regarding this case, it would be around 1 258 kg of bycatch per day for the trawling fleet of El Puerto Santa María.

For invertebrates (20,9% of bycatch studied), a total of 47,02 kg (31% according to weight) was found, classified as follows (only mentioned the most representatives species): 22 species of crustaceans (2,09 kg of *Liocarcinus depurator*, 1,04 kg of *Dardanus arrosor* and 836,07 g of *Calappa granuata*), 5 species of cephalopods (1,09 kg of *Eledone moschata*), 13 species of bivalves (1,31 kg of *Anomia* sp., 230,2 g of *Atrina pectinata* and 235,6 g of *Pteria hirundo*), 13 species of gastropods (1,51 kg of *Galeodea* sp.), 10 species of echinoderms (2,05 kg of *Astropecten* sp., 1,63 kg of *Astropecten irregularis* and 808,22 g of *Paracentrotus lividus*), 7 species of cnidaria (714,19 g of *Calliactis parasítica*, 717,08 g of *Pteroeides spinosum*, 519,56 g of *Diphasia margareta* and 456,08 g of *Pennatula rubra*), 3 species of polyquats (762,2 g of *Aphrodita aculeata*, 82,64 g of *Filograna implexa* and 24,97 g of *Sipunculus nudus*), 3 species of tunicates (24,69 kg of *Molgula* sp.), 3 species of sponges (383,62 g of *Suberites dumuncula*, 139,74 g of *Aplisyna* sp. and 30,98 g of *Dysidea* sp.), and 1 species of bryozoan (14,01 g of Cheilostomatida order).

From Aquaculture and Seafood Processing Industries

Like at the national level, this information is confidential and it is not available.

From auctions

Like at the national level, no bycatch reaches auctions, only commercial species. The bycatch generated after the auctions business is very scarce and they are usually donated.

3.3.2 B. Marines By-products

According to Andalusian by-products management, no by-products are generated from fisheries, aquaculture industries or auctions. Respect to seafood processing industries, the information related is confidential.

3.3.3. Conclusions

Even though there are no national regulations for **bycatch** (only at European level), a huge amount of them is caught every day for the **national fishing fleet**, being the **trawling fleet**, which

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catches more quantities of bycatch. According to the boarding studies, 34% of catches are bycatch (**3 500 tons/year**), of which 40% of them correspond to commercial species, discarded for different reasons. These data match with those supported by the official entities in charge of controlling the amount of bycatch (**Spanish Ministry of Agriculture, Fisheries and Food**). There are already some **proposals** to improve the control and management of bycatch, such as the selectivity of fishing techniques or informatic applications for the online bycatch registration.

On the other hand, not much information is available about **aquaculture and seafood processing industries** (first processing (wholesalers) and second processing (canneries)) due to the fact that these data are private, while in **fish auctions** there is no registration of bycatch due to the low amount of them (occasionally). However, **seafood industries** are the sector that generates the highest quantity of by-products, according to indirect resources. Although they could use these by-products for **revalorization** and obtain new food products, they do not take widely advantage of this opportunity because they usually do not have **enough quantity of bycatch** to efficiently industrialize the process in their own business.

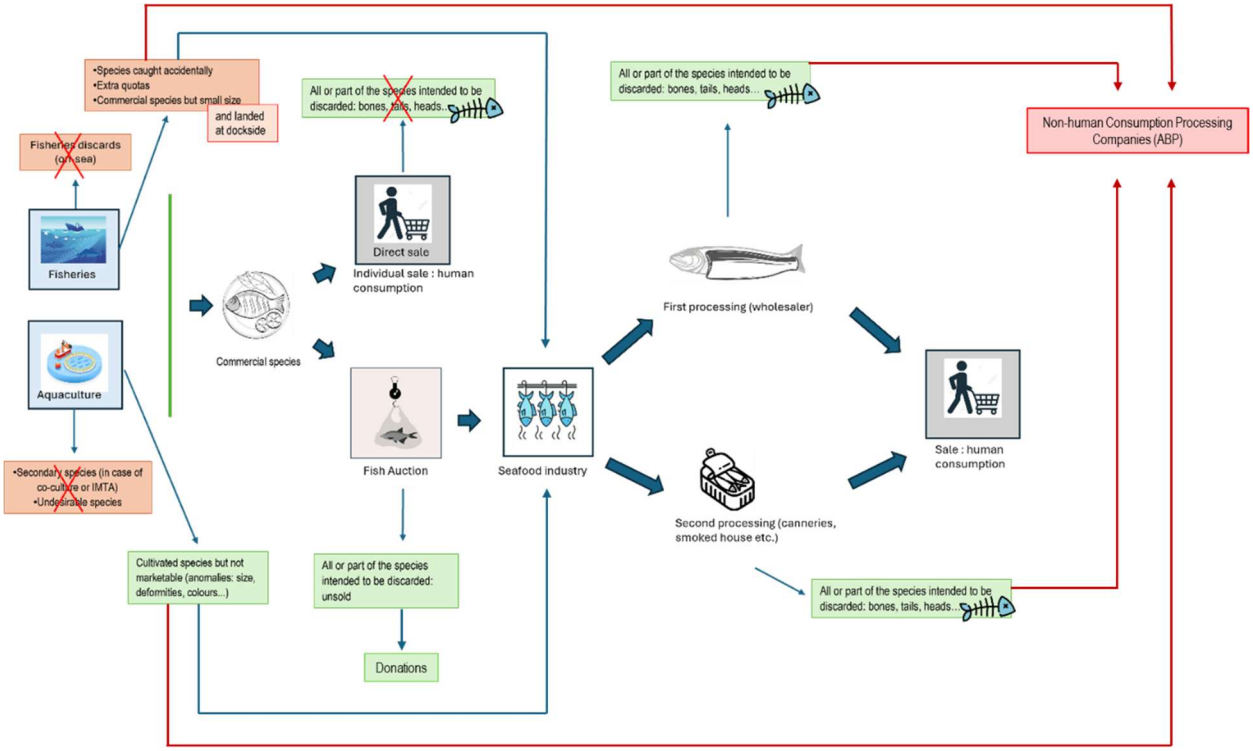

***Figure 18**: Illustration of the value chain of the management of bycatch and by-products.*

The Figure 18 (above) represents all the **companies/industries involved in the value chain about commercialising products and management of aquatic bycatch and by-products**. Bycatch are generated by fisheries, auctions (when all the fishes are not sold) and aquaculture industries while by-products are generated by human food processing industries (first and second processing), which could use bycatch generated by others and its own by-products for the development of their new high added-value products for human consumption. Those bycatch and by-products not exploited are destined for ABP companies, which could be specialized in pharmaceutical, cosmetic, feed or other business, such as textile or new bio renewable sources, being feed industries where the most of bycatch and by-products are destined for elaboration of fishmeal.

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According to this, the **use of bycatch and by-products for the development of new human consumption food products should be promoted**, since most of them are currently destined for fishmeal production. To achieve this purpose, it is necessary to improve the obtaining process of bycatch and by-products, to guarantee a sufficiently high quantity of them (being profitable for the companies) and a correct quality of them (being suitable for human consumption).

According to the data collected, there is a gap of information in the value chain of bycatch and by-products. The databases of the corresponding Spanish Ministry (MAPA) show a huge annual quantity of bycatch obtained and landed by the fisheries. Those bycatch could be destined for donations (not much due to the scarce preservation capacities of these entities), for human processing industries (not much because of the low current quality of bycatch obtained, especially from fisheries) or collected by ABP companies (the majority) and distributed to different destinies: elimination, fishmeal and other applications such as, pharmaceutical or cosmetic industries; while all by-products not used by the seafood processing industries are destined for ABP companies.

As this information is the property of private ABP companies and is not publicly available, there is an important information gap on the final destiny of bycatch and by-products. However, there is an indirect estimation about the use of bycatch and by-products from fishmeal industries (where the most of these materials are destined), in which more than 90 % of them come from human food processing industries and less than 5 % from fisheries. This way, ABP companies are receiving by-products from food industries but there is no information about where bycatch from fisheries are going on, considering the huge amount of bycatch generated according to MAPA databases. Therefore, there is a lack of information due to the confidentiality of the companies involved in the value chain.

3.4 Portugal

By-products and derived products searched for this deliverable are of category 3, according to the Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009:

- “Aquatic animals, and parts of such animals, except sea mammals, which did not show any signs of disease communicable to humans or animals;”
- “Animal by-products from aquatic animals originating from establishments or plants manufacturing products for human consumption;”
- “The following material animals which shows no signs of disease communicable through that material to humans or animals:
    - Mollusc shells and crustacean shells with soft tissue or flesh;”
- “Aquatic animals, aquatic and terrestrial invertebrates, with the exception of species pathogenic to humans.”

In order to estimate the biomass volume of marine by-products produced / available in Portugal, several methodologies were used:

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Direct methodologies:

- Questionnaires – were sent by email to various companies in the aquaculture industry and fish processing industry. In this questionnaire, we asked the following questions:
  - Company name.
  - Business area.
  - Quantity of marine by-products (category 3) generated in 2022.
  - Main types of by-products generated.
  - Do you separate by-products?
  - What is the main destination of the by-products?

  Unfortunately, as of the date of this deliverable, we haven't had any responses to the questionnaire.

- "Estatísticas da Pesca" (Fisheries Statistics compendium) – official fishery statistics published by National Institute for Statistics (INE) and the Directorate-General for Natural Resources, Safety and Maritime Services (DGRM). This compendium is published every year on the 31th of May (Fisherman's Day). The data available in this compendium concerns:
  - Fisheries landings,
  - Fish auction rejections,
  - Aquaculture production,
  - Fish processing industry production.

Indirect methodologies:

- Through bibliographical research, it was possible to find some conversion coefficients that allowed us to get an approximation of the volume of by-products produced by the fish processing industry.

Challenges:

- Absence of data regarding by-products and bycatch from aquaculture,
- Absence of data on the production of by-products from the transforming industry,
- Lack of response to questionnaires sent to various companies in the aquaculture industry and fish processing industry,
- Lack of availability and time to address further contacts.

3.4.1 National scale

Based on the information gathered, we have constructed a schematic of the production of marine by-products in Portugal (**Figure 19**), which allows us to identify 4 sources of marine by-products (category 3):

- Fisheries discards;
- Aquaculture by-products;
- Rejections from fish auction;

- By-products from the fish processing industry.

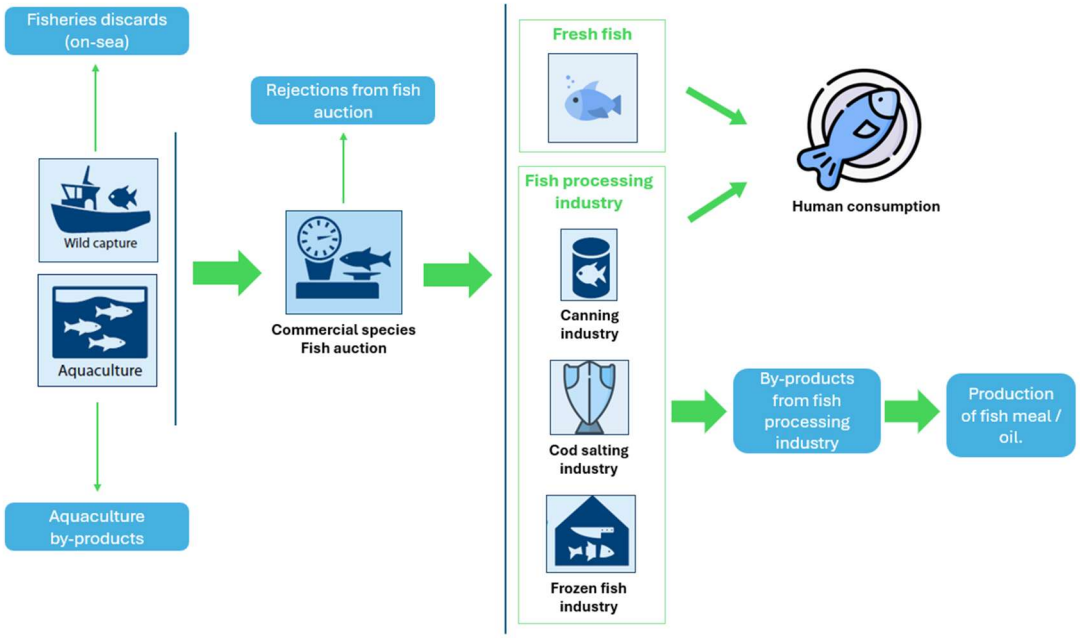

Figure 19: Schematic illustration of the production of marine by-products (category 3) in Portugal.

3.4.1A. Bycatch

From Fisheries

Landing of accidentally caught species is almost non-existent in Portugal, since fishermen return the fish to the sea while on-board. On-board discards are composed of low commercial value fish species, non-targeted species (bycatch) or undersized targeted species. The percentage of discards varies within the fishing methods since it depends on the selectivity of the fishing gears employed.

3.4.1B. Marine By-products

From Aquaculture

There was no data available on marine by-products produced in aquaculture.

Fish processing industry

In Portugal, the fish processing industry is divided into three sub-sectors: canning industry, cod salting industry and frozen industry. The marine by-products generated by the fish processing industry are mainly fish residues. From previous studies (Sotelo *et al.*, 2011) in Portugal, the

canning and frozen fish industries are the ones producing the largest volume of marine by-products. These by-products are valued for the production of fish meal/oil.

Regarding the by-products produced by the fish processing industry, no data were available. However, literature shows two studies that provided information on the by-products produced by the fish processing industry. Sotelo *et al. (*2011) estimated the by-products produced by the canning and frozen fish industry in 2009, and Nunes (2012) presented a conversion coefficient that allows the estimation of the by-products produced by the fish processing industry.

- Canning fish industry:

  Sotelo *et al. (*2011) estimated that the amounts of by-products generated by the sardine and mackerel canning industries, in 2009, were around 19 600 tons/year (with the contribution of sardines being around 1 485 tons).

  According to Nunes (2012), the volume of by-products produced by the canning industry is equivalent to ~40% of the canning industry production. Therefore, considering that the canning industry production, in 2022, was 56 624 tons, one can estimate that the volume of by-products produced in 2022 was 56 524 x 40% = 22 650 tons (see **Table 12 and Figure 21**).

- Cod salting industry:

  There was no data available about the quantification of by-products produced by the cod salting industry.

- Frozen fish industry:

  Sotelo *et al.* (2011) estimated that the volume of by-products generated by the frozen fish industry, in 2009, was around 11 970 tons.

  According to Nunes (2012), the volume of by-products produced by the frozen fish industry is equivalent to ~15% of the frozen fish industry production. Therefore, considering that the frozen fish industry's production in 2022 was 125 603 tons, one can estimate that the volume of by-products produced in 2022 was 125 603 x 15% = 18 840 tons (see **Table 12 and Figure 21**).

Auctions: rejections

Fishing ports and auctions contribute to the generation of by-products in the form of whole aquatic animals as opposed to the fish processing industry that contributes with animal parts. In Portugal, the marine by-products generated by auctions are stored in containers and further collected by transporters to the fish meal factories (Docapesca. *pers. comm.*).

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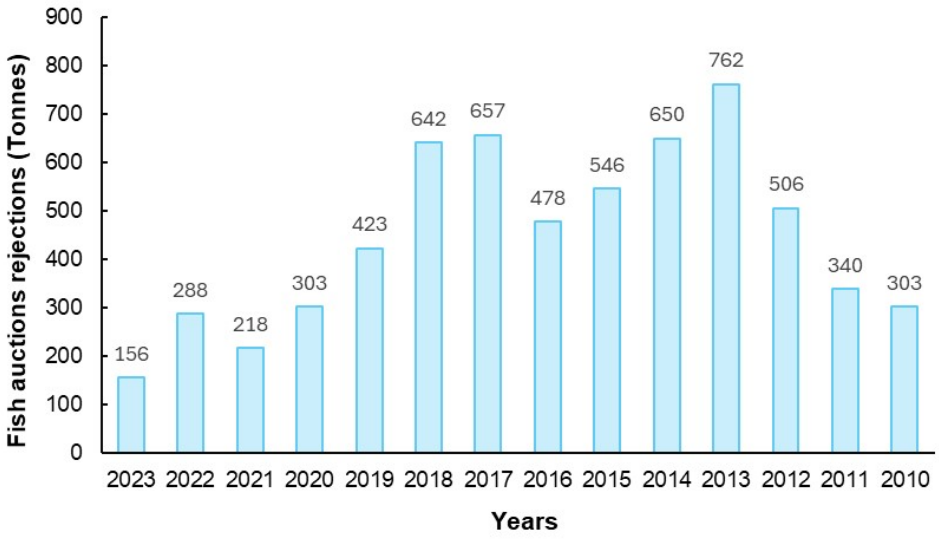

Figure 20: Evolution of fish auction rejections, only category 3, between 2010 and 2023 (source: INE, 2010 - 2023).

On Portuguese fish auctions, rejections are fish that didn't pass the veterinary sanitary inspection in the auction – category 2 (this data is sent to the Portuguese National Institute of Statistics by the General Directorate of Veterinary – DGAV) and also fish that was impossible to commercialize – category 3 (this data is sent to the Portuguese National Institute of Statistics by the General Directorate of Natural Resources, Security and Maritime Services – DGRM). **Figure 20** shows the evolution of fish auction rejections, only category 3 data, between 2010 and 2023. Rejections ranged from 156 tons in 2023 to 762 tons in 2013. On average, the percentage of fish auctions rejections represents 0,3% of auction landings.

Estimation of marine by-products in Portugal

Types	Production in 2022 (tons)	% by-products conversion coefficient	By-products (tons)
Residues of fish from aquaculture	18 822	?	?
Residues of fish from canning industry	56 624	~ 40% (Nunes, 2012)	~ 22 650
Residues of fish from cod salting	71 621	?	?
Residues of fish from frozen industry	125 603	~ 15% (Nunes, 2012)	~ 18 840
Unsold fish from auctions	121 069	-	288
Total	**-**	**-**	**~ 41 778**

Table 12: *Estimation of marine by-products produced in Portugal in 2022*

Based on the information gathered, we have tried to estimate the volume of marine by-products produced in Portugal for the year 2022. **Table 12** and **Figure 21** show how we estimated the volume of marine by-products produced in 2022, which was approximately 41 778 tons.

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However, it is important to stress that the coefficient used to calculate the volume of by-products produced by the fish processing industry is based on data from 2012. It is expected that, in 10 years, companies will have made improvements in order to reduce the volume of by-products produced, so the estimated value of by-products for 2022 may be lower than the value presented.

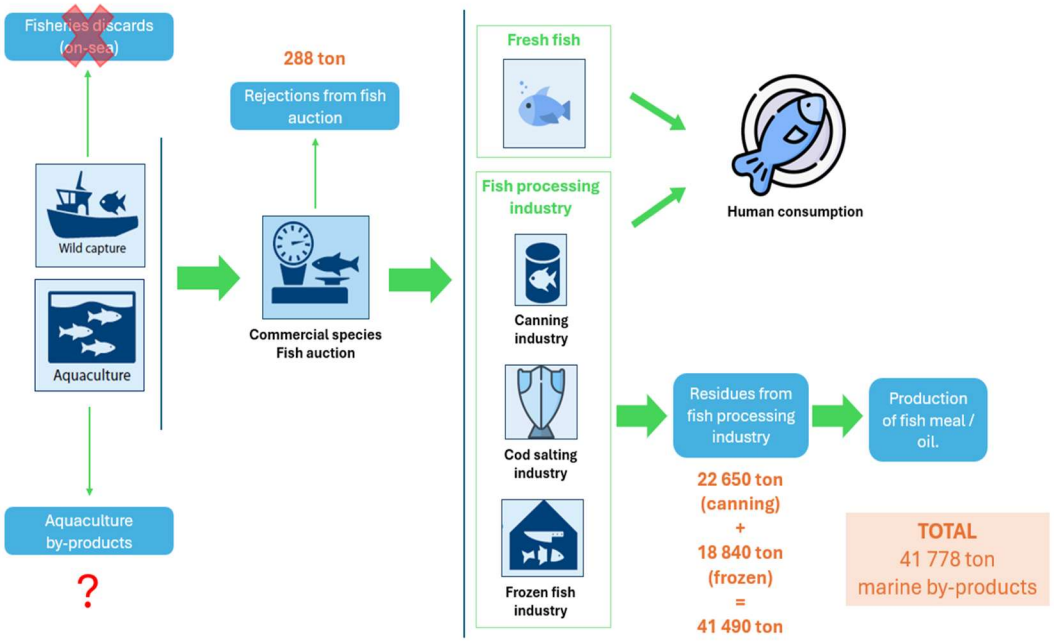

Figure 21: Schematic illustration of the production of marine by-products (category 3) in Portugal, with the estimation of the marine by-products in 2022.

3.4.2 Regional scale

3.4.2A Bycatch

Fisheries

Landing of accidentally caught species is almost non-existent in Portugal, since fishermen return the fish to the sea while on-board.

3.4.2B Marine By-products

Aquaculture

There was no data available on marine by-products produced in aquaculture at regional scale.

Fish processing industry

There was no data available, at regional scale, on marine by-products produced by the fish processing industry.

Auctions: rejections

Figure 22 and **Table 13** show the evolution of fish auction rejections, at regional level, between 2010 and 2023. Fish auction rejections are higher in the centre and north of Portugal, accounting for around 61% of fish auctions rejections. In the islands, Madeira and Azores, fish auction rejections are practically non-existent.

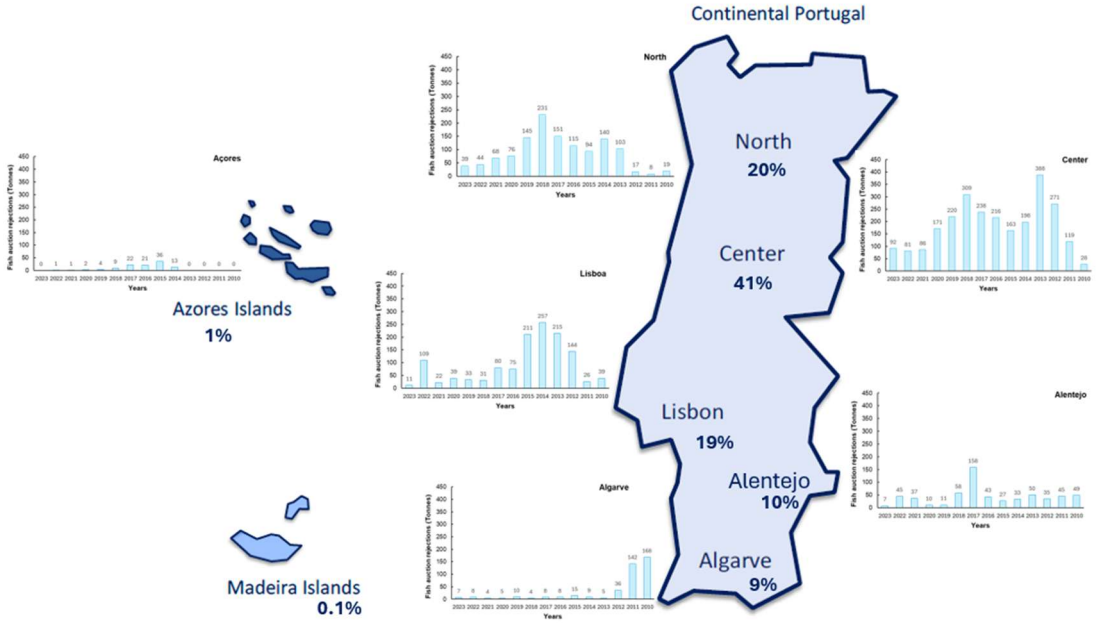

Figure 22: Schematic illustration with the evolution of fish auctions rejections, at regional level, between 2010 and 2023 (source: INE, 2010 – 2023).

Region	Minimum (tons)	Maximum (tons)	Medium ± standard deviation (tons)
North	8	231	89,29 ± 63,50
Center	28	388	184,29 ± 99,26
Lisbon	11	257	92,29 ± 82,54
Alentejo	7	158	43,43 ± 36,59
Algarve	4	168	30,64 ± 53,54
Azores islands	0	36	7,79 ± 11,25

Table 13: *Minimum, maximum and medium ± standard deviation of the fish auction rejections, at regional level, between 2010 and 2023 (source: INE, 2010 – 2023).*

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3.5 Ireland

Fisheries, aquaculture, seafood processing and associated economic activities such as domestic consumption, private investment, exports-imports in Ireland can be collectively described as 'The Irish Seafood Economy' these sectors had an estimated combined GDP of €1,2 billion in 2023.

The value of Irish Seafood was placed at €637 million in 2023 (BIM, 2023) indicating a decline of 9% from 2022 figures. This is the value of all fisheries landings into Irish ports and all domestic aquaculture production.

Ireland reported 1 988 registered fishing vessels, 282 aquaculture sites and 103 seafood processors, employing (directly & indirectly) 15 673 people in 2023 (BIM, 2023).

Ireland is estimated to be the fifth highest EU member state in terms of fisheries catches. Eurostat (Eurostat. 2022 Statistics) estimates of live weight catches in 2021 were 200 000 tons, all taken from Northeastern Atlantic waters. Ireland has a 5,2% share of the EU catching fleet (based on 2022 of gross tonnage).
Aquaculture production in Ireland stood at 35 700 tons, valued at €169 million in 2023, the bulk of national production was comprised of;

Finfish (mostly Atlantic Salmon *Salmo salar*): 9 900 tons.

Shellfish (mostly Rock oysters *Crassostrea gigas* & Mussels *Mytilus edulis*): 25 800 tons.

Data pertaining to national aquaculture production is gathered directly from industry by way of an annual survey conducted by BIM – Ireland's Seafood Development Agency. The survey is conducted through direct data collection from approximately 250 primary producers, the survey is conducted annually with data being collected for the previous calendar year. The survey seeks a response rate of 100% for the production related data, generally the survey achieves response rates of 80%. Estimations, based on comparing non-respondents to similar neighbouring production units or localised feedback on production performance or using publicly available data are used to create estimates to overcome the 20% cohort of non-respondents.

The bulk of Irish shellfish aquaculture production is sold fresh and live, usually having undergone at most depuration, grading, and packing only. The volumes of by-product generated are typically quite low, the majority of by-product is thought to be 'doubles' (multiple individuals that have fused during the growing cycle) mortalities and damaged individuals (predation, handling and other impact or interference related damages) These by-products typically represent a low percentage of overall production and are resolved at the business level. Typically, these by-products are unsuitable for processing, sale or donation. By-product volumes can be quite low volume, unpredictable according to seasons or activities, irregular and fragmented across many businesses rendering any processing, holding or accumulation mostly impractical and/or uneconomical. Mass mortality events and product recalls etc. do occur occasionally, however these events by their nature and their causes render the by-product unsuitable for the food chain and these streams are usually dealt with through appropriate disposal techniques for biological wastes. Therefore, for the purposes of this study, these streams have been discounted.

Finfish production in Irish aquaculture in a normal year, is typically between 13 000 tons and 15 000 tons per annum, (2023 being uncharacteristically low by volume) the bulk of the production is organic salmon (*S. salar*) and lesser quantities of Rainbow Trout (*Oncorhynchus mykiss*). This sector has a relatively well-developed supply chain and by-product handling system.

Typically, the finfish sector starve (producers curtail feeding briefly to allow animals to naturally empty digestive system in advance of slaughter) slaughter and bleed fish immediately on harvest, studies indicate that blood volume is approximately 3,5% - 4% of live weight (Dominiguez et al, 2024), weight loss also occurs during the starving process. Viscera is usually extracted by machine and treated, stabilised and stored for sale/export for processing into food and nutritional additives. The bulk of Irish salmonid (Salmon & Trout) production is sold as "Head on, Gutted" to domestic and international customers, and this has the effect of reducing the quantity and variety of potential by-product that the sector can produce or access (Table 14).

	Atlantic salmon
Live fish	100%
Loss of blood/starving	7%
Harvest weight / Round bled fish (wfe)	93%
Offal	9%
Gutted fish, approx. (HOG)	84%
Head, approx.	7%
Head off, gutted	77%
Fillet (skin on)	56 - 64%
C-trim (skin on)	60%
Fillet (skin off)	47 - 56%

Table 14: *Typical Atlantic salmon yields – Taken from Salmon Farming Industry Handbook 2023, published by MOWI.*

Secondary processors generally remove heads, tails, skin, 'frames' (the spinal column, some radiating bones and tails). These waste streams represent opportunities for reprocessing but without adequate and regular volumes of high-quality by-product, careful separation and efficient recovery of by-product, reprocessing and recovery can be a marginal economic activity.

Estimating biomass of by-products and bycatch in Ireland from fisheries, aquaculture and processing has proven to be complex and the availability of significant, reliable data and estimations is rather limited. There are a few official sources of statistics and estimates for catches, landings, aquaculture production and imports, however, the disaggregation of these statistics to by-product and bycatch volumes has proven to be difficult. A study by Pfieffer (Pfieffer, 2003) estimated the volumes of fish and fish processing waste being generated in Ireland at the time, the study reported that the pelagic sector produced 39 263 tons of Total waste, the whitefish sector 7 724 tons and Salmon and Trout combined 5 543 tons, the study estimated national production of 63 889 tons of total waste across 13 species in total. A study by Attard & O' Connor (Attard and al, 2022) for the Environmental Protection Agency estimated that fishing and aquaculture wastes and losses (combined) during primary processing amounted to 4 872 tons in 2020. Dominguez et al (Dominguez et al, 2024) based on capture fisheries of 184 761 tons and aquaculture production of 13 381 tons, Ireland had an estimated by-product range of 110 857 tons - 129 333 tons for capture fisheries and 8 029 tons – 9 367 tons for aquaculture.

The work of Giron-Dominguez and Gaffey (Giron-Dominguez, C., Gaffey, J ,2024) on the InformBio project reported that 13 species of finfish (produced from fisheries and aquaculture) generated

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21 667 tons of 'secondary feedstock' from seafood processing, with an additional potential 13 100 tons of waste being generated from mussel and pacific oyster production.

The Sea Fisheries Protection Authority (SFPA) is the national agency responsible for fisheries control in Ireland, the agency has a wide remit and many areas of responsibility including monitoring, inspecting and enforcing compliance in numerous areas such as; quota compliance, minimum landing sizes by species, appropriateness and legality of catching gears utilized, geographic areas of fisheries activities and product handling and food safety and control. The SFPA reports a wide range of data on fisheries and aquaculture, for the purposes of this work, fisheries landings data are critical.

The 2023 statistics for Ireland are as follows in Table 15 and Table 16 (SFPA Annual Statistics 2023);

	Events	Tonnage
Total number of Landings	44 396	
Total Landings in Ireland		244 989 t
Total Number of Landings outside Ireland by Irish vessels	584	
Total Landings outside Ireland by Irish vessels		30 124 t
Total Landings by Irish vessels		275 113 t
Total Number of Landings by Non-Irish vessels into Ireland	2.040	
Total Landings by Non-Irish vessels into Ireland		88 070 t
Total Landings into Irish Ports		363 183 t

Table 15: *Irish Fisheries Landing and Tonnages 2023 from SFPA statistics*

Species	Landings (tons)
Blue whiting (*Poutassou*)	103 579
Atlantic Mackerel	56 972
Boarfishes nei	16 212
Anglerfishes nei	12 564
European hake	11 952
Norway lobster	7 864
Edible crab	7 353
Haddock	5 977
Great Atlantic scallop	5 938
Whelk	5 757

Table 16: *10 Species representing the highest landings by volume in Ireland in 2023 from SFPA statistics.*

To complete the picture on total seafood processing, seafood imports of seafood into Ireland were 150 600 tons in 2022, the most significant quantities comprising of Seaweed (75 000 tons : This category is difficult to disaggregate and may comprise a significant quantity of raw material for non-food applications) Blue Whiting (21 600 tons) Salmon (7 400 tons), Shrimps & Prawns (4 900 tons) Cod (4 800 tons) and Tuna (4 600 tons). These imports can contribute significantly to co-product and by-product generation in Ireland.

Direct data collection remains the most important source of data on Fisheries, Aquaculture and Seafood Imports; various agencies and organizations collect statistics on production, capture, Import and trade in seafood.

Commercial landing statistics are gathered and collated by the Sea Fisheries Protection Authority, this is implemented through a regulated and enforced reporting obligation on vessels (vessel log book) in advance of quayside landing of fish.

Bycatch statistics, including unwanted catch statistics are gathered through a combination of industry self-reporting (vessel log book) and the work of on-board fisheries observers deployed and overseen by the Marine Institute, the national Marine Research agency and competent Marine Scientific advisors to the Irish Government.

The EU Landing obligation was introduced in 2015 and has been in force since 2019, it applies to the following;

"all catches of species regulated through catch limits (such as mackerel) or minimum size (such as anchovy in the Mediterranean) should be landed and counted against the fishers' quotas"

"undersized fish caught and landed should not be used (sold) for direct human consumption, but for products such as pet food, fish meal, pharmaceuticals, and food supplements"

The EU Landing obligation covers catches that are defined as unintended catch of quota and regulated species, such as quantities over and above regulated limits or individuals that are outside of specified parameters and limits e.g. undersized individuals.

Unwanted catches can be defined as non-landing obligation species (not regulated by catch limits or minimum size) such as those of no commercial value or interest or non-landing obligation species that are caught while not being targeted in fisheries activities and/or commercially valuable species outside of regulatory parameters (sizes / area of activity etc.).

Bycatch estimates are generated by direct onboard observation work conducted by the Marine Institute, trained observers are deployed to a representative cohort of vessels.

The SFPA provides an interactive map of national landings on their website which breaks down landings by port (volume and value) further detailed breakdown by species are also available (Figure 23 and Figure 24).

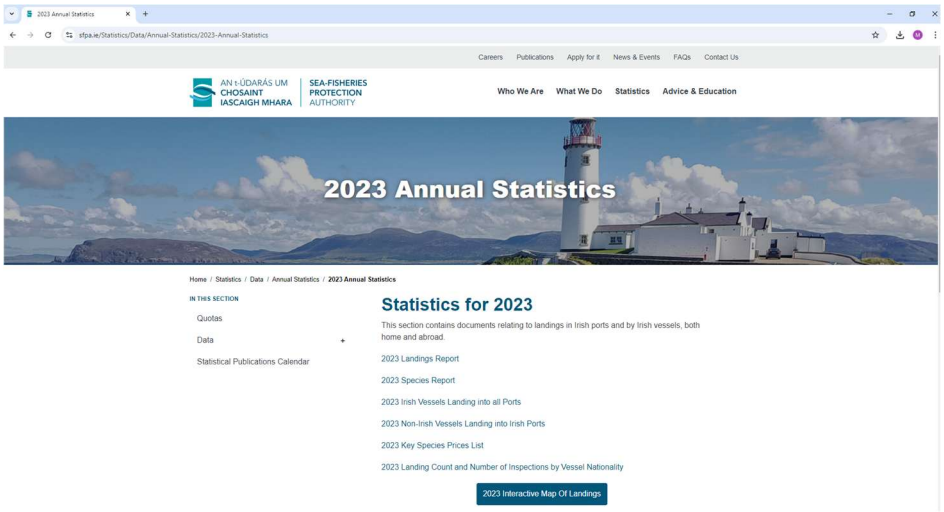

***Figure 23**: Screen shot of SFPA Website 2023 Annual Statistics https://www.sfpa.ie/Statistics/Data/Annual-Statistics/2023-Annual-Statistics.*

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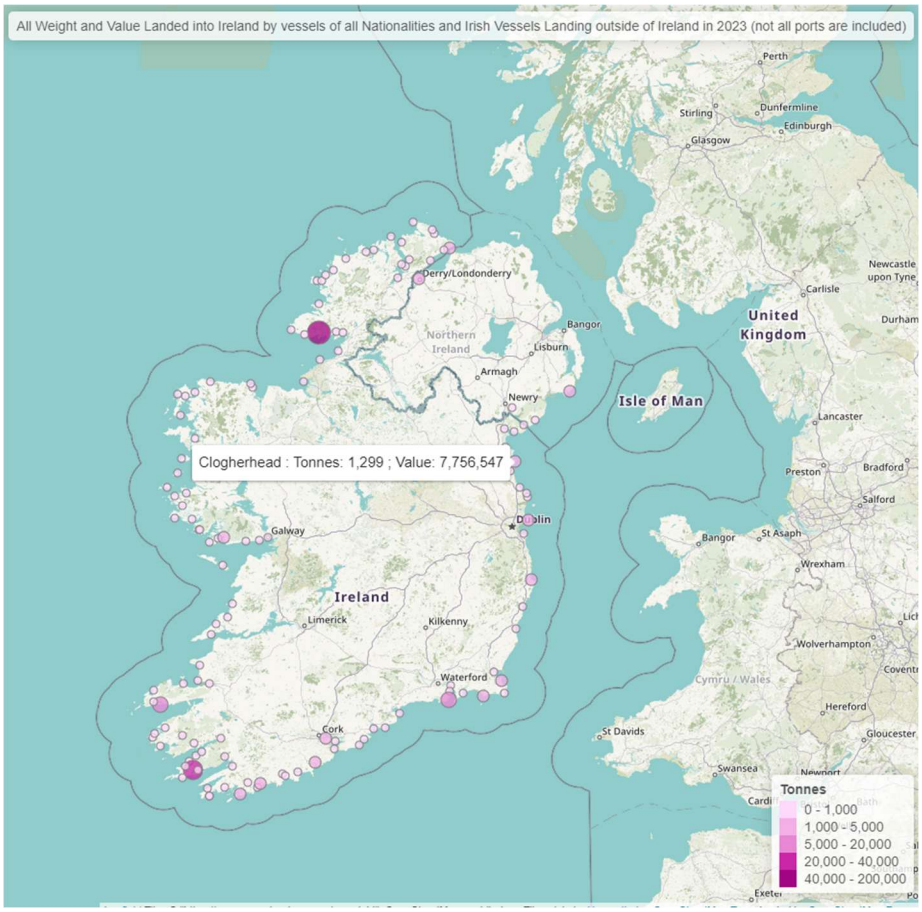

Figure 24: *Screen shot of SFPA Interactive map of national landings 2023, showing landings at Clogherhead. https://www.sfpa.ie/Statistics/Data/Annual-Statistics/2023-Annual-Statistics.*

1.2 National scale

There appears to be little enough data on biomass volumes of by-product or potential by-product available as of time of writing (2024), however, several studies and projects have been undertaken and these provide a basis for the national picture of biomass availability to emerge. Several projects are underway to assess and estimate the potential volumes of by-product that could be generated from a range of species, these projects will investigate the potential generation of by-product from various sources including the domestic processing of quota species and aquaculture species.

The overall picture for co-product, by-product production in Ireland is that little of national production of by-product and co-product is being diverted to applications outside of fishmeal and fish oil production. There appears to be a recognition of the potential of value creation within co-product and by-product sectors but that technical and market and knowledge obstacles exist to value adding opportunities.

The bulk of production and processing co-product and by-product arisings in Ireland appears to be directed to fishmeal and fish oil production, lesser amounts are directed towards the inshore fishing sector to be used as fishing bait. Smaller quantities are being directed towards a variety of applications such as pet feeds and novel / experimental development applications. Overall

co-product generation (for human consumption) appears to be relatively insignificant in the overall national context. Data on the various sectors and applications is sparse and data collections efforts face a number of obstacles incl. fragmentation of production, seasonal fluctuations, production fluctuations and inconsistent reporting (Table 17).

Source	Estimated By-Product or Production, Processing Solid Wastes	Note
Giron-Dominguez., G and Gaffey., J. 2024	21,677	Processing waste from 9 species.
Pfeiffer, N. 2003	63,889	National study, multiple species.
Attard, J., & O' Conner, T, 2022.	4,872	National study, 22 species.

Table 17: *Estimates of by-product production, production and processing solid waste generation in Ireland. Commas in the table numbers separate thousands from the rest of the number.*

InformBio is a project with the stated goal of "InformBio will support preparations for a bioeconomy observatory for a sustainable and circular bioeconomy. The project will deliver a Bioeconomy Foresight Analysis providing a clear roadmap for Ireland towards a sustainable bioeconomy, along with the tools to rigorously measure progress towards this objective. InformBio combines data driven research, analysis and modelling with input from expert thematic groups, ensuring robust and informed outcomes for industry, policy makers and other relevant groups (Figure 25 and Figure 26)".

The project website continues; "By integrating biomass mapping, value-chain analysis, life-cycle assessment and scenario modelling, the project, for the first time, attempts to quantify the potential of the bioeconomy to contribute to Ireland's climate and sustainability targets. Moreover, the project positions Ireland as a front-runner among EU member states, by developing a prototype national bioeconomy monitoring system, enabling Ireland to track the development and progress of the bioeconomy against key bioeconomy indicators."

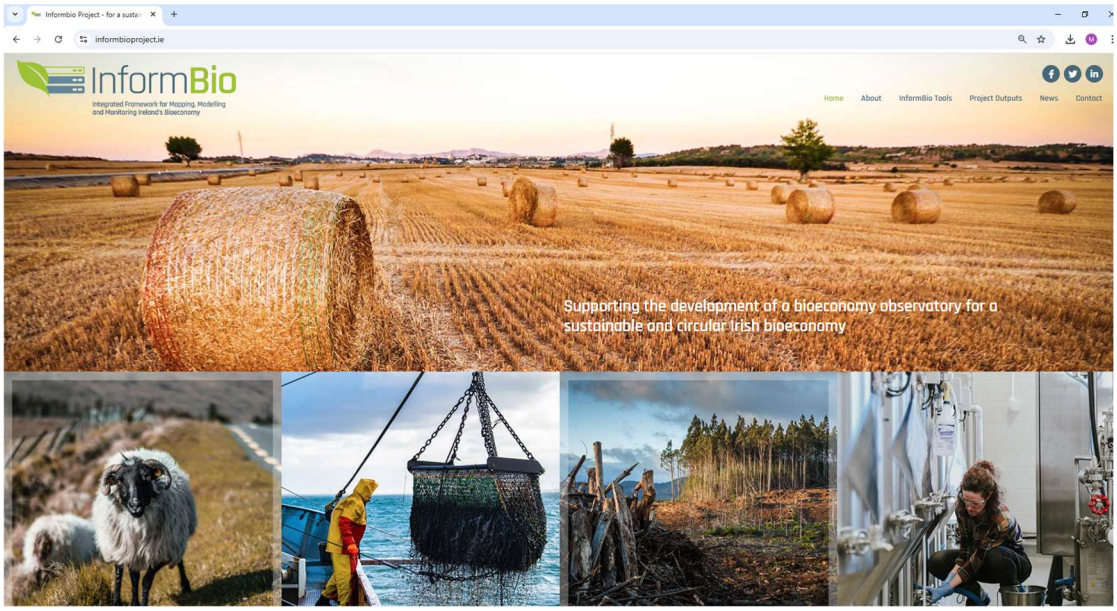

Figure 25: *Screenshot of homepage of https://informbioproject.ie/.*

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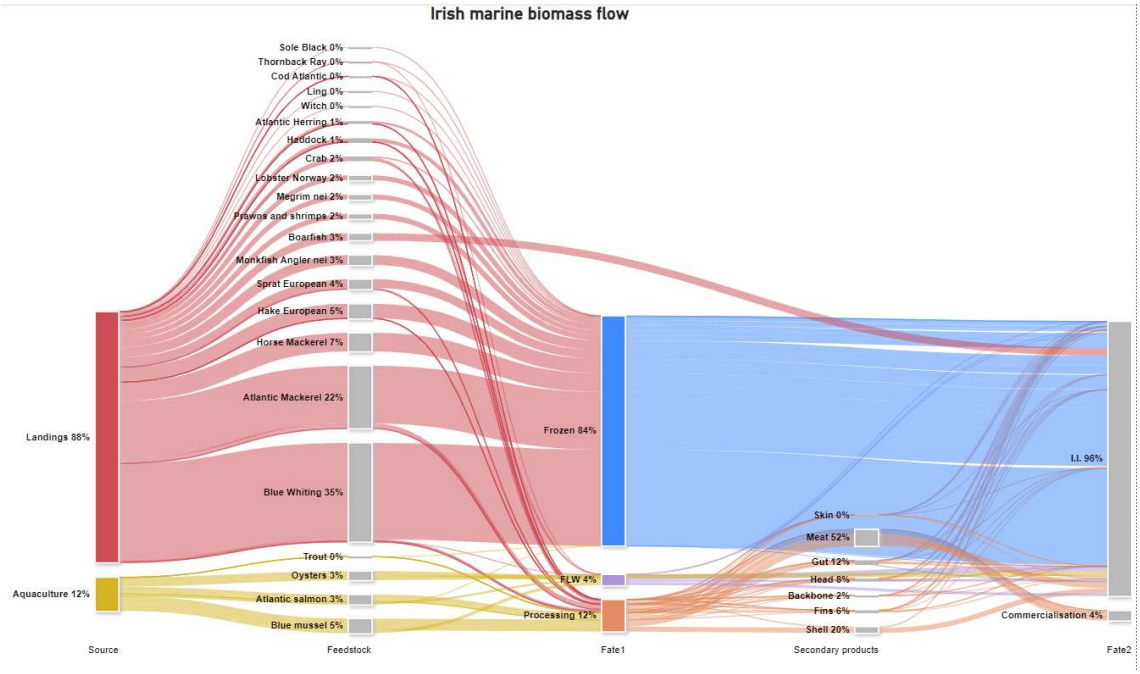

***Figure 26**: Sankey diagram with aquatic animal biomass flow in Ireland in 2020. Source https://informbioproject.ie/.*

Species	Gut (Average 19,2% of live weight)	Head (Average 12,9% of live weight)	Skin (Average 2,6% of live weight)	Meat (Average 43,1% of live weight)	Backbone (Average 12,2% of live weight)	Fins (Average 10% of live weight)
Atlantic salmon	1 927	1 298	31	4 332	147	1 005
Trout	101	68	2	226	8	53
Atlantic Herring	100	67	3	225	14	52
Atlantic Mackerel	1 357	914	4	3 050	20	707
Blue Whiting	632	426	84	1 421	403	330
Cod Atlantic	3	2	0	8	2	2
Haddock	25	17	3	55	16	13
Hake European	94	63	13	212	60	49
Sprat European	458	309	-	1 030	-	239
Total	4 697	3 165	139	10 559	668	2 449

***Table 18:** Estimated secondary feedstocks and meat arising from fish processing activities in Ireland. Data in tons of live weight. Source https://informbioproject.ie/.*

Country	Captures	Estimated Range of by-Products Weight	Estimated Range of Viscera Weight	Aquaculture	Estimated Range of by-Products Weight	Estimated Range of Viscera Weight
Ireland	184,761	110,857–129,333	14,781–27,714	13,381	8029–9367	1070–2007

***Table 19:** Excerpt of estimations from Dominguez et al, 2024. Commas in the table numbers separate thousands from the rest of the number*

Table 18 and Table 19 based on estimates based on assumption of by-products being 60-70% of total eight of capture and aquaculture production, viscera assumed to be 8-15% of total weight.

Seaweed Sector

Information from the informbio project states that the seaweed sector in Ireland produces approximately 34 356 wet tons of seaweed (wild harvested) *Ascophyllum nodosum* represents 98% of national production (33 703 wet tons: Socio-Economic Study of Seaweed Harvesting in Ireland. The Clean Technology Centre and the Circular Bioeconomy Research Group, MTU and Benton Ecological Solutions and Technology). The sector also imports an unknown but potentially significant quantity of unprocessed calcified seaweed for primary processing in Ireland. The sector produces minimal to no waste and by-products are repurposed for other applications like fertilizers, animal feed and cosmetics. The project did not provide an estimation of the potential by-product production from the seaweed sector.

Technical Trials and Data Collection

It is estimated that as much as 35% of produce from fisheries and aquaculture are lost or wasted each year (FAO 2020). This loss can take the form of damaged, underutilised or wasted products from this sector. As part of BIMs Circular Seafood Group (which provides support in the sustainable development of Ireland's blue bioeconomy), one of its ongoing projects is to develop an estimate of the available raw material from the processing sector which could form a feedstock for bioeconomy applications. As part of the project, a base principles approach was required which necessitates the development of a yield's dataset for hand processed seafood. These yield values will be used to estimate the potential volumes of by-products that are generated on an annual basis by the Irish seafood sector.

During 2024 trials were commenced on the main national landings species, there was an emphasis on species landed at higher volumes and species that were routinely processed in Ireland. The trials consisted of manual filleting of various legal landing size ranges of important species by a highly skilled fishmonger to create reliable estimates of edible fillet volume and potential by-product yield based on species length and weight. This data may be used as the basis for a model of expected yields from various species to generate by-product estimations in future.

Currently the Irish seafood sector catches or farms over 130 species. The volumes of these species range from over 50 000 tons to 100 kg. Given this wide range, the project has started by estimating the yields and availability from the top 10 species by volume.

This project consists of three phases:

1. Generation of data on species which are predominantly hand filleted (this phase has been completed and a report is in preparation). This includes haddock (*Melanogrammus aeglefinus)*, hake (*Merluccius merluccius)*, monkfish (*Lophius piscatorius)* and whiting (*Merlangius merlangus)*.
2. Capturing data on pelagic species which are machine filleted and sold in bulk. This phase will focus on mackerel (*Scomber scombrus)* and Horse mackerel *(Trachurus trachurus*). Atlantic salmon will also be included within this phase of the project. This phase will commence in January/February 2025.

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3. Develop and capture data on edible yields and by-products from crustacean and shellfish species. This phase will focus on whelk (*Buccinum undatum*), prawns (*Nephrops norvegicus*) and brown crab (*Cancer pagurus*). This phase is planned to commence in March 2025.

Initial findings suggest that there is a correlation between size/length of many important species and the expected fillet yields and possible by-product yields that can be generated post filleting, should further analysis support the initial findings, then it seems reasonable to assume that useful estimates of potential by-product generation from a number of key species could be generated during 2025 and beyond.

4. VALUE CHAIN OF BY-PRODUCTS AND BYCATCH

4.1 Context / Rationale

One of the ambitions of the project is to stimulate the sustainable production, processing of innovative seafood, based on a circular-economy approach and to raise awareness of the need to implement policies and reduce food losses and waste among producers.

We have suggested to carry out interviews to companies that already valorize by-products for human consumption in order to precise our analysis.

These case-studies will contribute to the project's objectives by allowing to:

☞ better understand the levers, risks and issues of existing circular initiatives and the value chain of marine by-products. It will help to put it into perspective and provide learnings for the Aquafish pilots,

☞ inspire as good practices, one of the key principles of the Interreg programmes.

4.2 Methodology

The value chain of marine by-products and bycatch is analysed combining biomass estimation and carrying out interviews for case studies.

The interviews will give useful information to identify (Table 20):

- The production & value chain dynamics for the marine by-products valorization: how is the value chain organised from upstream to downstream (from the arrival of raw materials to the product ready for use or consumption)?

- Capacities, bottlenecks & challenges for these value-adding activities (challenges & opportunities): perception of the challenges and opportunities linked to the marine by-products valorization for human consumption.

Targeted companies for Case Studies interviews are:

- Seafood Companies with a circular model,
- Companies that are already using marine by-products to develop food products (food, ingredients, supplements).

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Questions	Objectives *(what type of data we want to obtain)* / Analysis model sub-questions
Axis 1: Production & Value chain dynamics for the marine by-products valorization	
Before: • Can you describe the raw materials you use to add value to seafood by-products? Which species? Which parts (head, viscera, etc.)? Which necessary quantity? Where does it come from? In what form do you receive it (fresh, frozen, ...)? • How and where do you obtain these by-products (from whom?)? • Do you have any specific constraints for this raw material: seasonality, traceability, regulation, variability, cost, storage constraints, impact on sustainability of the activity? **During:** • Can you briefly describe the recovery process you use to transform co-products into finished products? (*not in detail*) (the whole raw material or extraction %) • How do you manage the waste produced during the recovery process? • What are the technical constraints in the production process? **After:** • How many final products do you produce from co-products (T)? • To whom do you sell these final products and in which sectors are they used? • What are the constraints regarding the market (seasonality of sales, variability of demand, acceptance, storage constraints, regulations (novel food…)) ? • What is the technical and economic profitability of obtaining by-products? • Is the marine by-products valorization integrated into your marketing approach to customers?	Analysis of the dynamics of production & value chain for the marine by-products valorization: how is the value chain organised from upstream to downstream (from the arrival of raw materials to the product ready for use or consumption)?
Axis 2: Identify capacities, bottlenecks and challenges with these value-adding activities (SWOT) (eco, environmental, social)	

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Concerns & challenges • What are, in your opinion, the main challenges facing the marine by-product recovery industry? – And at company level, what are the main challenges you face (environmental, technical, regulatory, economic and social) (internal and external factors of the company)? • In your opinion, what are the conditions for success to engage in by-product valorization activity? **Areas for improvement & opportunities:** • In your opinion, what are the main points for improvement in the process of valorizing seafood co-products within the company? • What actions could be taken to overcome the previous obstacles and challenges encountered mentioned? • Do you have any new projects in terms of marine co-product valorization (new product, new process, new raw material)?	Perception of the challenges and opportunities linked to the marine by-products valorization for human consumption

Table 20: Case Studies Interview Grid.

4.3 France

Three interviews with by-product valorization experts were conducted. Each of these interviews provides insights into a different raw material (shellfish, fish by-products and algae). Each interview is presented and analyzed separately as a "case study," highlighting the value chain of each experience along with its strengths, weaknesses, opportunities, and threats. Verbatim quotes from the three interviewees complement these case studies. Subsequently, a cross-analysis emphasizes the key success factors and risks identified through commonalities and differences between these experiences.

4.3.1 Case study n°1

A. Presentation

This company, based in Brittany and employing around twenty people, has been marketing ingredients for the high added value dietary supplement market for about ten years, using marine by-products from fishing.

B. Business model

Supply Chain

The company processes several hundred tons of by-products annually. These include frozen sardine by-products (heads, flanks, scales, small-sized sardines), fresh ray cartilage, and white fish bones. Sardine by-products are sourced from fish processors and canning industries, while

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white fish bones and ray cartilage come from suppliers that process their own fish by-products. In this case, these are "by-products of by-products."

The company prefers to source locally (Brittany, Normandy). Most suppliers are located in France, although some are in other European countries (e.g. Ireland). The fishing area is primarily FAO Zone 27, occasionally extending to FAO Zone 34 for sardines. The company ensures product traceability through supplier specifications, including quality questionnaires and site inspections.

Processing

Both bones and ray cartilage arrive with residual flesh, requiring an initial washing process before either enzymatic hydrolysis extraction for cartilage or direct grinding for bones. Sardines and cartilage undergo enzymatic hydrolysis extraction, with process parameters (pH, enzymes, etc.) adjusted for each product. The solid phase is separated to produce a liquid phase ("the juice"), which is further refined to isolate the most soluble components. Concentration and drying steps follow to yield powdered products.

Organic waste generated during these processes, such as cartilage residues and fish scraps, is collected by animal feed manufacturers. Fat extracted during processing is also reclaimed by these companies.

Sales and Distribution

The company sells its ingredients in the dietary supplement market, offering a product line of around ten items, including "premium" and "commodity" products. Annual production totals several dozen tons of finished goods, marketed as capsules, sticks, or gummies.

Its customer base is diverse and evenly distributed across France, Europe, and international markets:

- **Supplement brands:** These develop their own formulations and products for sale.
- **Contract manufacturers:** They work for brands or private labels, sometimes developing their formulations with the company's ingredients.
- **Distributors:** Primarily located abroad, they sell products directly to customers, leveraging their market expertise.

Single orders rarely exceed several hundred kilograms, especially for premium products, where initial purchases are often under 100 kg. Commodity products are sold in tons, though the company aims to reduce these volumes over time.

C. Key factors of success and risks

Strengths

The company boasts strong innovation capabilities, thanks to significant investment in R&D, which constitutes a large portion of its workforce. This allows it to conduct studies demonstrating the effectiveness of its ingredients, enhancing sales and differentiation from competitors.

A diversified supplier network ensures stable supply, mitigating stock shortages. Using frozen raw materials enables year-round production, despite seasonal fluctuations in fishing or raw material collection.

The company employs processes that overcome microbiological constraints, simplifying supplier requirements: *"We know the raw material isn't necessarily clean from the start—it's impossible to demand a raw material free from any flora. That's not an issue, as our processes handle that. What matters is ensuring food-grade compliance and that the material isn't sourced from improper conditions."*

Additionally, the company benefits from a well-distributed and diversified customer portfolio, enhancing resilience against market fluctuations. Future growth projects, such as diversifying its product range with algae-based ingredients, further bolster its market position.

Weaknesses

The company heavily relies on outsourcing, lacking its own industrial facilities. This limits control over technologies and the optimal valorization of waste. Plans to internalize production are under consideration to better control the value chain and increase margins. Energy-intensive drying processes also pose challenges.

Threats

Regulations pose a significant threat, particularly regarding raw material quality for food applications. Strict requirements could classify products as "Novel Foods", requiring additional studies, regulatory costs, and technical constraints. Market approval can take years.

Cost pressures in a market driven by "cost-per-dose" dynamics challenge the company to deliver effective products at competitive prices. Rising energy costs, especially for drying, may further impact profitability.

"One challenge is the effective dose our product requires. The market dictates acceptable doses. We might have an excellent product, but if several grams are required for a dose, no one will buy it. Alternatives with lower doses exist, so dose considerations must align with market expectations early in R&D."

Seasonal variations in raw material characteristics (e.g., fat content) affect processing. This necessitates blending batches from different periods or requiring specific purchasing agreements to standardize products, crucial for the dietary supplement market: *"We need standardization, but the risk is producing raw materials tailored to our needs rather than valuing existing by-products that would otherwise go to waste. We must avoid reversing the original goal."*

Seasonality also impacts the supply chain, as reduced demand in summer aligns with decreased availability of some by-products. Overfishing, climate change, and quotas raise concerns about the future raw material supply.

D. Perspectives

The rising consumer demand for transparency presents an opportunity for the company to highlight its brand assets on client packaging. Historically focused on France, the company is

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now exploring promising international markets, facilitated by partnerships with local businesses that provide insights into regional dynamics.

4.3.2 Case study n°2

A. Presentation

For over 30 years, this company has specialized in the harvesting and processing of seaweed, selling it for human consumption in various forms.

B. Business model

Sourcing

The raw material used is seaweed, with five to six species utilized (sea lettuce, dulse, sea beans, wakame, royal kombu, and nori), amounting to 80 to 90 tons processed annually. The seaweed is harvested from organic-certified areas. Half of the harvest is conducted in-house (accounting for half of the supply), while the other portion is provided by Breton seaweed harvesters or a European seaweed farmer (Portugal). In France, all harvesting follows the *Guide to Good Harvesting Practices*. A very small portion is also supplied by French seaweed farmers.

Processing

The first step involves washing and preserving the seaweed: impurities are removed before coarse salt is added (quantities depend on the desired finished product). The seaweed is then stored until further processing. A desalting stage follows to remove the previously added salt. After that, the process mirrors that of more conventional vegetables. Cutting and treating the seaweed allows it to be transformed into purée or pieces. A mixture is then prepared by adding oils, spices, etc., followed by portioning. For certain products, a thermal treatment such as sterilization or pasteurization is performed. Otherwise, the product is offered fresh. Very little waste results from this process.

Sales/Downstream

The finished products are primarily intended for end consumers in various forms: spreads, fresh, sterilized, or pasteurized products. Less processed seaweed (e.g., flakes) is sold as culinary aids to other industries.

The company supplies several types of clients in France, Europe, and internationally:

- **Purchasing groups for the out-of-home catering sector** account for half of the turnover (revenue).
- **Large and medium-sized retailers** represent about a quarter of the turnover.
- **Fine grocery stores, specialized organic networks, and industrial clients** make up the remaining turnover.

C. Key factors of success and risks

Strengths

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Having an in-house seaweed harvester ensures efficient management of field operations and minimizes seaweed loss through regular monitoring of intertidal zones. This local expertise improves control over harvesting activities.

Additionally, the company benefits from a network of multiple suppliers, ensuring secure sourcing and a broader harvesting range. This diversity also helps maintain a strong territorial presence.

Thanks to its long-standing presence in the industry, the company can anticipate market trends and potential outlets (notably in cases of overstock) due to a deep understanding of sector dynamics.

The R&D department is a major asset, as evidenced by numerous innovation awards. This ability to develop new product innovations (such as flavour combinations) and processes strengthens the company's competitive position.

Weaknesses

The fragility of seaweed poses a significant challenge, requiring precise control of parameters throughout the process, from selection at sea to processing.

"We face constraints because seaweed remains a delicate product. If we draw a parallel with lettuce—it's like cutting and cooking lettuce. You need to precisely control these parameters to avoid creating mush or overcooking it. So yes, there are many factors that can influence the quality of the finished product, starting from the sea selection stages themselves."

Another weakness is the lack of communication resources. Convincing consumers requires investment in marketing campaigns or advertisements, which is currently beyond the company's capabilities, thereby limiting market growth.

Threats

The market for these products is currently quite limited (a niche market), making it highly dynamic and competitive. It is also sensitive to various events or disruptions (e.g., COVID-19).
Moreover, persuading consumers to purchase seaweed-based products can be challenging since it is new and not part of established eating habits. A bad experience with one product could tarnish the perception of seaweed in general, requiring significant investment in communication and marketing to overcome this barrier.

"The problem is that if the consumer's first experience with seaweed is negative, they won't think a specific brand isn't good—they'll think seaweed isn't good and will steer clear of it for 10 years. It's crucial that the product tastes good because otherwise, it undermines the entire sector."

Additionally, despite the company's intentions, developing nori-based products is not feasible. This is due to the low availability of this biomass, the lack of a specifically defined seaweed field, and the difficulty of ensuring stable production. As a result, sufficient volumes cannot be guaranteed for purchasing groups. In the past, the company could sell nori-based products by negotiating directly with clients.

Finally, the lack of European support for algae farming of high-interest species like nori—favouring other species like wakame where the market is already saturated—is also seen as a barrier by the company, as noted during the interview.

D. Perspectives

Despite being a niche market, it is steadily growing, offering reassuring visibility for the industry.

"What reassures us is that this growth is gradual. We're not dealing with a fad—this isn't bubble tea that will disappear in three years. It's really something that's taking root, and that's reassuring for the sector."

Seaweed is also seen as a food of the future, addressing many consumer concerns: plant-based, local, healthy, and environmentally friendly.

"There are many seaweed players trying to establish themselves because seaweed rides on the plant-based, local, health, and environmental preservation trends."

The presence of the "Merci Les Algues" association for several years helps promote and highlight all seaweed-based food products, which is a real asset for the company.

4.3.3 Case study n°3

A. Presentation

In recent years, the company has been developing an activity centred around the valorization of undersized shellfish for human consumption.

B. Business model

Supply

The raw materials for this activity are sourced from the company's other operations on the same site. After washing shellfish sourced from numerous producers along the Atlantic and English Channel coasts, undersized shellfish are recovered on a separate processing line.

Process

These products are processed fresh. Once washed, the undersized shellfish undergo an enzymatic hydrolysis process, resulting in shells devoid of meat and a protein-rich liquid. The shells are dried and ground into powder, which can then be used in animal nutrition, furniture manufacturing, construction, and other applications. Following hydrolysis, the resulting protein liquid is evaporated and concentrated to create the final liquid product. In some cases, this product is converted into powder by a subcontractor.
This activity generates minimal waste, primarily consisting of broken shellfish or undesirable materials (e.g., plastic, stones, crabs) that escaped the initial sorting process.

Sales/Downstream

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The products, available in liquid (more or less concentrated) or powdered form, are intended for human consumption and are offered to professionals as food ingredients (PAI market in France). This flavouring can be used to make sauces or added to pâtés, ready-made meals and other dishes. The primary markets for these products are international (e.g., Asian countries), though some opportunities exist within France.

C. Key factors of success and risks

Strengths

The company has several key strengths contributing to its success in valorizing undersized shellfish for human consumption.

A major strength is its robust sales force, essential for prospecting new markets, both in France and internationally. This strength is bolstered by the company's other activities, which provide a strong commercial foundation. Additional recruitment is planned to enhance this capability.

A dedicated space for this new activity ensures optimal production organization, equipped with modern, innovative machinery tailored to their needs. This innovative equipment addresses cleaning challenges posed by the product's texture, reducing health risks and energy consumption.

"The challenge with processing a semi-liquid product containing minerals is that it's difficult to pump. So, we designed a gravity-fed process to avoid these pumping issues. This also addresses cleaning challenges. When you hydrolyze, you release amino acids, which are essentially fertilizer for bacteria. With heat and pre-cut products, the process inherently carries a high risk."

The product itself offers significant advantages. Its French origin is particularly appreciated, especially in Asian markets. Due to the processes used, the product's organoleptic and taste qualities differentiate it from competitors.

The company's flexibility, adaptability, and openness are additional strengths. It can adjust the dry matter content of the final product based on client demand. Moreover, other projects involving the valorization of additional marine coproducts are under consideration to utilize the production line outside the shellfish season, maximizing the use of its facilities year-round. However, further adaptations of their line and processes will be required depending on the chosen projects.

Weaknesses

The implemented process poses a challenge as it is energy-intensive (water, electricity, and gas). This requires optimization, particularly through industrial improvements. Switching energy sources is not currently feasible, as gas remains the most efficient, cost-effective, and stable option in terms of supply. To enhance energy efficiency, the process must run in three shifts (24/7 operation), which requires recruiting line operators and technicians as production scales up.

Reliance on subcontracting for powder production (as this cannot be done in-house) is another weakness. However, this arrangement appears to function well and is not perceived as a significant barrier by the company.

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"Subcontracting works very well; you just need to fine-tune your process. Powder production via subcontracting is efficient. While facilities in Brittany are somewhat saturated, slots and providers can be arranged without issues."

The relative youth of the activity raises another challenge, with limited experience regarding the markets and processes. Market studies have provided insights into potential prospects. However, in terms of processes, the company is still relying on theoretical data, lacking real-world operational metrics that are crucial for optimization.

"At this stage, we're still working with theoretical data provided by suppliers. Getting accurate estimates for gas consumption is extremely complex because thermal inertia factors are challenging to evaluate during studies. We hope—and believe—we'll end up below estimated levels, as suppliers often build a margin into their predictions. If this is the case, it will allow us to run more cycles."

Threats

Regulations pose a significant threat to the activity. Companies must choose between human or animal feed production (excluding pet food) as it is not permissible to produce for both markets on the same production line. The company had hoped to enter certain segments of the animal feed market alongside the human food sector.

Additionally, intra- and inter-annual production variability is a potential threat. Production levels vary yearly based on weather conditions, potentially leading to supply issues.

"The lower the yields, the more undersized shellfish we'll have. This year, for example, there's a significant surplus of undersized shellfish compared to last year, and this is highly weather-dependent. We've had a lot of rain and little sun this year, so it hasn't been a high-yield season."

Seasonal variability is another challenge. Since the shellfish are processed fresh and are only available part of the year, the production line remains idle during the off-season. To address this, the company is exploring alternative coproducts to process during downtime.

The product format also poses challenges. The limited shelf life of the liquid format creates time constraints for clients, who are less inclined to purchase this format. Additionally, international sales of the liquid format are constrained by higher transportation costs (liquid = heavier weight).

Finally, in the French market, the company faces international competition offering similar products, though the organoleptic and taste qualities of its products are a competitive advantage.

D. Perspectives

The finished product's properties present an opportunity to replace a controversial additive used as a flavour enhancer in many industrial preparations. This is a substantial market opportunity, particularly abroad, given the high usage of this additive. Other markets are also

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open to them (e.g., dietary supplements, pet food), although the animal feed market (excluding pet food) is closed due to regulatory issues.

4.3.4 Analysis of value chain and inventory

Each of these case studies provides insights into the existing success drivers and limiting factors for the development and sustainability of co-product valorization initiatives in Brittany. We will explore some commonalities and differences among the three companies studied.

The Role of Company Tenure

The age of the company appears to be a key determining factor. For example, the company in Case Study 2, thanks to years of accumulated experience, benefits from better strategic foresight, allowing for more accurate predictions of uncertainties and market opportunities. Conversely, Case Study 3 highlights how the youth of a company can be a drawback due to a lack of market knowledge and insufficient testing of new processes. However, this remains an unavoidable challenge that must be considered when launching a valorization initiative.

Optimizing and Securing Supplies and Markets

The three companies emphasized the importance of diversifying both their suppliers and their clients. This enables them to optimize and secure both their sourcing and market opportunities. Diversification emerges as a critical element for maintaining and developing their operations. Moreover, seasonality in production can be a challenge for some initiatives. This is particularly the case when the company processes fresh products, as seen in Case Study 1 (for some of their raw materials). This constraint does not apply if the raw materials are used in frozen or salted forms (e.g., for seaweed), provided there is sufficient storage capacity. Working with frozen or salted materials thus helps overcome the seasonality constraint.

Markets and Commercialization Modes

While all these companies have markets in France, they also sell a significant portion of their production internationally (European and non-European markets). This suggests that there are more opportunities abroad than in France. Based on the insights gathered, the French market for fish co-products appears to be much more advanced and mature compared to the other two. Conversely, the seaweed market, although stable, remains niche, while the market for shellfish co-products is still young, particularly in France, with international markets dominating.

Regarding commercialization modes, two companies primarily operate in B2B, while one is focused on B2C (Case Study 2). These case studies show that it is much simpler to convince another business than an individual consumer (as contact is more direct). On the other hand, persuading consumers requires greater communication efforts. This observation is particularly relevant for younger companies, which often have more limited financial resources to invest in marketing. Under these conditions, support from seaweed valorization association “Merci Les Algues” could offset this limitation by broadly promoting the type of products in question (e.g., seaweed-based food products) rather than specific brands.

Market demand plays a crucial role in determining product quality requirements. For instance, in the dietary supplement market, products need to be even more standardized compared to other human consumption markets. This is due to the critical importance of product effectiveness in this market, which also serves as a major marketing asset.

Managing Regulatory Constraints

Regulations represent another significant barrier to the development of these activities. They impose strict requirements on raw material quality, necessitating rigorous monitoring and specific expertise to ensure compliance with standards. The companies address this through internal traceability measures or by setting specifications for their suppliers. In some cases, processes are used to circumvent certain health constraints (Case Study 1). This regulatory impact is not limited to human food markets: discussions with a seaweed user working in agriculture revealed that constantly evolving regulations also hinder development, requiring continuous adaptation to new standards.

The Importance of Innovation and Exploring New Markets

A propensity for innovation, whether through process improvements or the development of new products, is another key to success. All the companies discussed their new projects, either underway or in the planning stages. Two of the companies also highlighted the importance of their R&D departments (conducting efficacy studies, creating new products, etc.), while the third emphasized the flexibility of its production line for processing new materials. Thus, remaining open to innovation is critical for staying competitive and meeting market and consumer demands.

Energy costs also represent a significant challenge, as many processes are energy intensive. To address this, some of the companies are adopting increasingly innovative and energy-efficient processes.

Additionally, the need for market exploration to identify new opportunities represents a major entry barrier. Efforts to prospect new markets and build strong commercial relationships can require significant investments in time and resources, making it challenging for new or resource-constrained companies to enter. This issue was particularly highlighted by the company in Case Study 3. To address this, some companies deploy significant sales forces and establish partnerships with actors already present in their target regions.

Summary

The diversification of supplies and markets, adaptation to international markets, experience, innovation, management of regulatory and energy constraints, and the capacity for market exploration are essential factors for the success and sustainability of companies involved in coproduct valorization in Brittany.

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4.4 Spain

4.4.1 Case study n°1

A. Presentation

The first case of study was carried out with the **production director of a fish farm**. He graduated in Administration and Direction of Companies, and he has been working for the actual company for the last 3 years, although he himself valued his experience on by-products valorization as low.

The company was founded in 1969 and since then it has been working on farming and production of rainbow trout (*Oncorhynchus mykiss*), through three farms with a total annual production of 3 000 tons of this species. Besides, the company also manages the wholesale of rainbow trout.

B. Business model

The company obtains the product (rainbow trout) from the fisheries (slaughtered and preserved in water-ice inside a box). Then, the product is submitted to a filleting or evisceration process. The final product is packed in recycled plastic or polystyrene boxes and carried to different logistic centres, being destined to markets.

During the filleting or evisceration process of trout, notable quantities of by-products of these species are generated, such as heads, entrails, bones and trims (fillets that do not pass the control test because of colour, spots, blood, deformation, etc.). These by-products are not used for the development of new human-food products through a transformation and revalorization step because the company does not have enough physical space for this purpose.

Instead, by-products generated are packed in a 600 L box and kept in a refrigerated container. Finally, preserved by-products are picked up by an ABP company, who treated them as C3 bio-waste (animal by-products from processing not optimum for human consumption because they could present a low risk for health in their actual nature) and use them for the elaboration of fishmeal for animal feed.

C. Key factors of success and risks

The key factors of success, according to the facilities and objectives of the company, are the knowledge to separate and manage correctly by-products generated, the limited space to elaborate new food products based on by-products, the ability of obtaining a novel and interesting product demanded by the consumers and the capacity of copy actual fish products using by-products.

According to the company, the main risk is the acceptance of consumers for your product. It means that people try a product and after that they want to purchase it again and implement it in their diets.

D. Perspectives

The company has into perspective two options with its by-products: the first one is to sell them to another industry able to process them and obtain a new food product (because of the lack

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of space), while the second one is to expand their facilities through a funding and then be able by themselves to revalorise by-products and obtain new food products.

4.4.2 Case study n°2

A. Presentation

The second case of study was carried out with the R&D-manager of a **fish transformation company**. He graduated in Marine Sciences and Environmental Sciences and he has been working for the actual company for the last 6 months. He has a notable experience on revalorization of by-products and is currently working in several projects about that approach.

The company was founded in 1993 and since then it has been working on the manipulation, elaboration and distribution of fish products, being a national reference in Almadraba Wild Red Tuna. The company also commercializes yellowfin tuna and octopus (fresh, frozen and deep-frozen).

B. Business model

The company has its own fisheries, where red tuna, yellowfin tuna and octopus are caught through different fishing methods. Then, catches are carried to the transformation industry, in which raw materials are processed (primary and secondary processing) and different food products are produced. As a consequence of this elaboration step, an important amount of by-products is generated in the industry. Therefore, all by-products managed in the company come from their own raw materials. By-products are obtained from the different species (tunas and octopus) and in different ways, fresh and frozen. Among the by-products generated there are octopus peaks, guts and shells of cephalopods, and tails, skins and heads of tunas.

The company has a strong compromise with the blue economy and the circular economy. This way, the company has the purpose of exploiting all by-products generated through different applications. The first objective is to use them for human food consumption. With respect to this objective, the company has already developed 4 food products based on by-products obtained in its own factory and from their own raw materials. These products, which are commercialised in national supermarkets, are composed of at least 80 % of tuna by-products. The rest of by-products (the majority) are destined for ABP companies and finally used for the elaboration of fishmeal.

C. Key factors of success and risks

The company informs that they do not have technical restrictions for the elaboration of the products (quantity of by-products, process, etc.) or other restrictions (regulations, seasonality, etc.) for the commercialisation of the obtained products.

The most relevant restriction could be the acceptability of the products based on by-products. For this reason, the company has carried out strategies to inform and make consumers aware of the different ways to consume fish products, including those based on by-products. Nevertheless, they are aware that the acceptability of these kinds of products takes time, so they claim that key factors are patience and perseverance.

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D. Perspectives

The company has the objective of exploiting by-products for the elaboration of food human consumption products looking for a blue circular economy with profits for the own company and at the same time the obtaining of these products with added high value.

4.4.3 Analysis of value chain and inventory

In comparing the seafood processing companies studied, it is clear that there are significant differences about the management of by-products and the restrictions and concerns of working with them depending on the facilities and capacities of the companies.

On one hand, there are models of companies that obtain their raw materials from external fisheries, that elaborate their products by primary processing (evisceration and filleting) and who generate a notable quantity of by-products. The concerns and bottlenecks of these companies are the knowledge of management of by-products from a technical and quality point of view and limits of space to increase the elaboration process with by-products (its first objective would be to externalize this production line). Moreover, the acceptability by consumers of these kinds of products based on by-products is a key factor.

On the other hand, there are other models of companies that have their own fisheries, that elaborate their products by a primary and secondary processing (evisceration, filleting and transformation) and that generate a huge amount of by-products. These companies already have the knowledge and high experience in managing by-products and in the elaboration of new products in their own facilities. The only bottleneck they have, like the other ones, is the acceptability of new products, especially those based on fish by-products.

As a conclusion, independent of the capacities of the companies, the main key factor and risk of the products based on fish by-products is the potential acceptability of the consumers, which will determine if a product has success or not in the market. Therefore, awareness strategies are necessary to inform consumers about these kinds of fish products.

4.5 Portugal

S2AQUACOLAB tried to contact the two largest by-products processing companies, Empresa Figueirense de Pesca, Lda (EFP) and Savinor UTS, to schedule an interview, but we were unable to get feedback from both.

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4.6 Ireland

4.6.1 Case study n°1 : Irish Seaspray (Oliean Mara Teoranta)

A. Presentation

Irish Seaspray is a salmon processor based in Co. Galway, the company is over 30 years in business and specialises in processing Irish organic salmon and retains a 'Country of Origin only' policy, i.e. uses only Irish raw materials in their production. The company produces smoked salmon and frozen salmon portions in consumer ready packs. The company purchases approximately 250 tons of salmon and produces approximately 140 tons of product per annum. The company has a strong emphasis on using organic (biological) status fish, sustainability, energy management and have implemented several worthwhile environmental initiatives, including the elimination of polystyrene boxes in favour or their own reusable boxes to transport raw material from suppliers, installation of state-of-the-art renewable energy generation.

B. Business model

The company produces smoked salmon products and frozen organic salmon products exclusively for export markets. The company produces mostly 'third party' branded products, i.e. products branded with the identity of their customers rather than their own identity. The company has built up a successful business supplying products to highly specialised retailers in Europe and North America, the emphasis on organic status, country of origin, quality certification and strong food safety systems have been a key element in developing their business. Circularity, waste elimination and high efficiency are critical parts of this businesses' success. Due to the relatively low volume of raw material being handled and the relative complexity and cost of recovering and reprocessing by-product, by-product processing is not a significant part of the company's activities.

C. Key factors of success and risks

The company seeks to eliminate waste at each opportunity and this carries through to their decision making when it comes to raw material sourcing. The company purchases scaled, Head On, Gutted (HOG) salmon.

This is the most common way that salmon is sold by Irish salmon producers. The removal of scales blood and viscera protects product quality and simplifies processing operations at secondary processing operations. ISS begin their processing with de-heading, the heads are removed manually, blast frozen, packed, stored, consolidated into consignments and sold either directly or via an intermediary for export markets. This product is intended for the human consumption market. Heads represent approximately 7% of animal live weight, within ISS, salmon heads represent 12% of co-product volume.

Filleting is an important step in processing, the company removes two fillets from each fish, the remaining 'frame' can then be stripped of the bulk of remaining viable flesh with a simple

manual scraping step if necessary. Previously, the company recovered 'scraped' flesh, this was collected for use in reformed products like salmon 'salami' (a simple sausage composed of recovered flesh and trimmings) which was intended to be smoked and packed for export markets, however, this opportunity was not pursued as the economic return on the activity was marginal.

Fillets are trimmed to customer specifications, this generates some additional waste stream, as described previously, this was intended to be incorporated into the sausage product, however, the company has kept to its previous application. The trimmings are set aside and repacked in consumer packs that are directed into the retail sector and used by consumers as an ingredient in home food preparation.

The filleted and scraped 'Frames' are generally frozen and stored and consolidated into viable consignments, before then being released into the by-product processing supply chain albeit at a nominal return, this activity is viable in that it saves disposal costs for frames and is not costly or overly onerous in terms of labour, handling and storage. In Ireland there is a single major processor of fish by-products, this processor mostly supplies the fish feed sector. ISS reported that frames represent 9% of their co-product volume. Moisture loss during processing can be 12% of volume, 8% as a result of salting and 4% during the smoking process. Skins amount to 2% of their HOG carcass weight and these are essentially the only waste being generated, skins are routinely sent for rendering by an animal by-products processor (Figure 27).

D. Perspectives

Irish Seaspray faces challenges with raw material supply as the national production of organic salmon is somewhat constrained, supply can be interrupted by weather and farm level losses, and demand regularly outstrips supply in Ireland.

The company only processes certified organic salmon that is produced in Ireland, this precludes the company from using available imports such as Faroese, Scottish or Norwegian salmon.

The volume of fish that the company processes is relatively modest and the company generates limited quantities of by-product material that could realistically be retained within the human food chain. The company makes all efforts possible to reduce waste and to retain as much value as possible from raw materials.

The company faces issues with the limited options available to them to generate by-products at a meaningful scale, at a viable price point to justify investment in adding value to by-products. The capital, labour and administrative cost of undertaking value adding activities is hampered by the level of raw material supply available, the consequent low level of by-product that is produced and the labour cost in recovering, handling and reprocessing these by-product streams mean that opportunities to work with by-product are relatively limited.

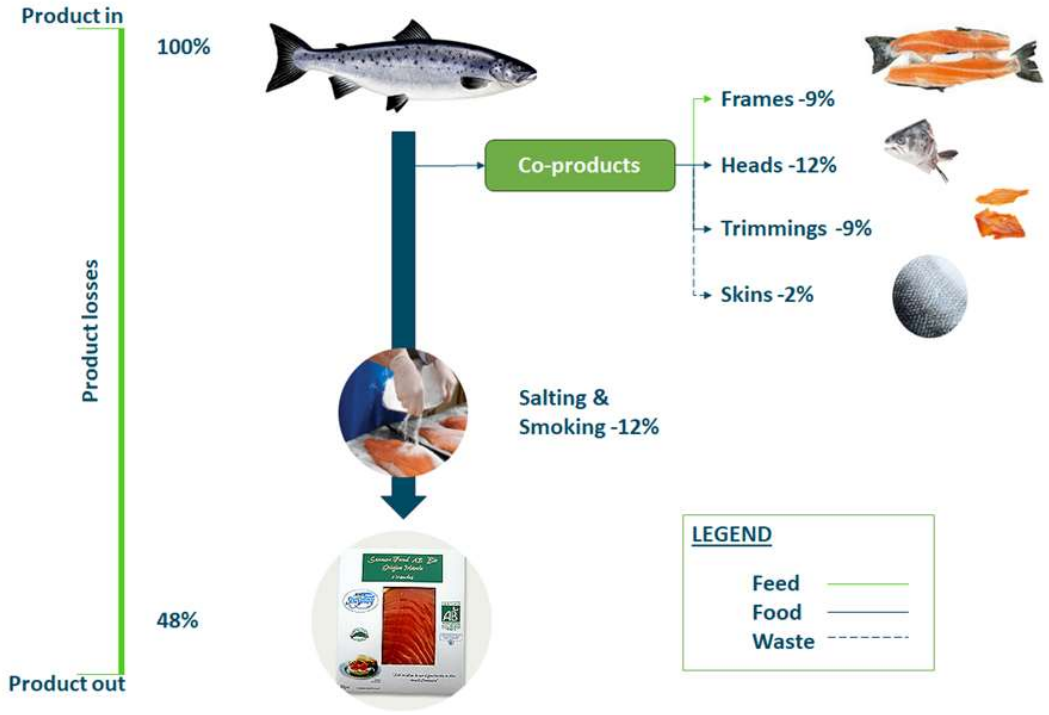

Figure 27: *The product losses and co-product valorization steps taken by Irish Seaspray. (September 2023).*

4.6.2 Case study n°2 : Pelagia / Port of Killybegs

A. Presentation

Pelagia Killybegs is a Fish meal and Fish oil producer based in Killybegs, Co. Donegal. The facility was built in 1957 and the operating company evolved with various changes in ownership over a number of decades
to be Pelagia Killybegs, a part of the Pelagia group. The company is a producer of fish meal and fish oil and is accredited by FEMAS to produce products for livestock, pet and fish feeds. The plant has a production capacity of 1 200 tons per day. The business is also certified by Naturland to produce fishmeal and fish oils for organic products. It is also certified with Marin Trust and MSC.

B. Business model

Pelagia Killybegs is a major player in the Irish by-product market, Pelagia processes significant quantities of Blue whiting *Micromesistius poutassou* which is fished and landed specifically for fishmeal and fish oil production. The company also processes a wide range of fish by-products which it purchases, consolidates and manages from a significant number of Irish seafood processors. Typically seafood processors arrange collection directly with Pelagia, and a service provider removes wastes regularly from the processors' premises. In the case of smaller scale processors, they are typically required to stabilise (freeze) and consolidate fish by-products for

a period until they have an economically viable quantity or when it is convenient for Pelagia or the processor to arrange removal of the by-product from the premises.

C. Key factors of success and risks

The port of Killybegs is strategically located adjacent to the north-south migratory paths and spawning grounds of many important and abundant pelagic species including mackerel (*Scomber scombrus*), Blue whiting (*Micromesistius poutassou*) and other species like Scad/Horse Mackerel (*Trachurus trachurus*). This makes the port a key fishing port for the Irish pelagic fleet and pelagic processing sector. This opens up opportunities for the port's stakeholders to access significant quantities of pelagic fish for processing, both fish specifically landed for processing into fishmeal and fish oil and significant quantities of by-product from the processing of fish at the port. The port can, and does, access landings from international vessels including British, Danish, Faroese and Norwegian vessels. The main risks to the port and its stakeholders are associated with reduction in access to raw materials. In recent years there have been the significant impacts of the United Kingdom leaving the European Union and the consequent reduction in Fisheries quotas for Irish vessels in British waters (particularly Mackerel quota) and the impact of CFP quota cuts driven by conservation measures. In recent years the fleet has lost significant quota for mackerel due to quota cuts agreed in the UK/EU withdrawal agreement; this has impacted quota allocations for Irish vessels, landings and earnings (Table 21).

PELAGIC STOCKS

SPECIES	Ices Area	2023	2024
Mackerel (Note 19) (DM)	6, 7, 8a, b,d & e; UK/Int 5b; Int 2a,12&14	52385	47560
Mackerel (Note 20) (DM)	EU 3a-3d; UK 2a; EU & UK 4; NO 2a & 4a	2495	1769
H. Mackerel & assoc. by-catches (Note 21) (DM)	UK & EU 2a and 4a; 6, 7a-c, 7e-k, 8a-b 8d-e UK and Int 5b; Int 12 & 14	3283	3182
H. Mackerel & assoc. by-catches (Note 22) (DM)	UK & EU 4b, 4c & 7d	194	198
Blue Whiting (Note 23)	UK, EU & Int 1-7, 8a, 8b, 8d, 8e,12&14	47737	59933
Herring (Note 24)	UK, Faroese, Norwegian & Int 1 & 2	2646	2019
Herring (Note 25)	6b & 6aN; UK & Int 5b	161	189
Herring (Note 26)	6aS, 7b & 7c	1720	2064
Herring (Note 27)	7a	439	218
Herring (Note 28)	7a South of 52.5N, 7g, 7h, 7j & 7k	750	750
Albacore Tuna (N. 29) (DM)	Atlantic Ocean, north of 5° N	3174	3967
Argentines	UK & EU 4, EU 3a	5	5
Argentines (DM)	6 & 7; UK & Int 5	573	593
Boarfish (DM)	6, 7 & 8	15749	18899
Blue shark	Atlantic Ocean north of 5° N	1	1
Total		131312	141347

Table 21: *Table of Irish Fishing Quotas 2024 (Pelagic Stocks). Source https://bim.ie/wp-content/uploads/2024/03/BIM-Fisheries-management-chart-2024.pdf.*

D. Perspectives

Continued access to appropriate quantities of raw material appear to be the key requirement for the port of Killybegs. The market for fish meal, fish oil and by-product derived commercial products remains strong and set to achieve continued growth. The raw material supply situation continues to be the most important issue for the Port of Killybegs, this is in terms of access to fish caught for processing for human consumption, fish caught for non-human food applications and also the continued access to appropriate volumes of by-product generated in the Irish seafood processing sector.

4.6.3 Case study n°3 : Shellfish Processor (Anonymized)

A. Presentation

Shellfish Processor is an Irish family company with expertise grounded in over 100 years of tradition and experience, yet driven by innovation in harmony with the environment. The company's origins lie in cultivating a wide range of the finest quality Irish shellfish products, which they also process, pack and distribute in both fresh, frozen and added value form throughout the world. The company concentrate efforts
on producing and exporting shellfish and crustaceans, mostly, but not exclusively, Mussels (*Mytilus edulis*) Oysters (*Crassostrea gigas*), Crab (*Cancer pagurus*), Razorfish (*Ensis ensis, Ensis siliqua*). The company sells both live and frozen products with Frozen products being dominated by processed (cooked) Mussels in consumer packs and individually packed cooked Crab.

Shellfish processing can generate significant quantities of by-product, especially when cooking, freezing and other high care steps are required to produce final products. The bulk of the by-product generated in shellfish processing tends to be as a result of quality control motivated rejection; undersized, damaged, contaminated (epiphytic contamination generally) individual animals that represent a risk to quality, shelf-life and food safety.

This business has created an innovative new method of handling shellfish shell waste, the company employs a large handling unit (approx. 10m^3) with a 'trickle through' low level watering system to enable the shells to clean naturally through gradual decomposition of remnants of protein and connective tissues. The system employs an air filtration system to manage odours. The system produces protein free shells that can then be sold for processing into a range of products, the process takes several days to complete a cycle and reduces wastes from several cubic metres of shell waste and rejects to a several litres of water per day. Shell waste and reject handling continues to be one of the most significant production issues for Irish shellfish producers.

B. Business model

This company operate a classical seafood processing business model in that they purchase shellfish from a wide range of sources in the supply chain (fisheries and aquaculture) and process, pack, transport and manage sales to a wide range of markets in Europe, Asia and North America, both under their own brands and in partnership with other businesses. The continued availability of raw material and ongoing demand for fresh and processed products are key to this business.

C. Key factors of success and risks

The most critical success factors for this company are their deep integration into the national seafood supply chain, the company has a highly effective purchasing and sourcing infrastructure and this is coupled with an extensive sales and distribution network on a global scale. The company plays a key role in consolidating, processing and adding value to a wide range of raw materials and the company has proven itself to be highly effective in identifying and developing new global markets in food service and retail from North America to East Asia. The company also has a highly effective processing capability and has demonstrated an ability to innovate new products with widespread appeal.

D. Perspectives

Raw material access and sustained national production of seafood are important for this company, as is the case with many Irish seafood processors, raw material is procured widely

from a variety of production sources and producers, a constriction in supply can impact producers as can increasing production costs driven by energy and labour costs can erode profit margin. Fluctuations in market conditions and consumer demand can also be significant issues. In terms of by-product streams and the handling of same, efficient, low cost methods of consolidating, handling and sale or disposing of by-products continue to be important.

4.6.4 Analysis of value chain and inventory

The value chain for Irish seafood by-products is a complicated situation, primary production is stagnant or declining for many valuable species. The main volumes of seafood landing occur in 2 distinct regions, the north west (45% fisheries landings by value) and south west (22% of fisheries landings by value) outside of these areas, landings, production and processing is relatively fragmented and dispersed, creating additional complexity for value adding in lower value materials like co-product and by-product. Pelagic species are the most important potential raw material source due to their higher volume quota allocations and landing, however, pelagic species are often 'round frozen' for export, this is a process which often entail minimal size reduction, cutting or alteration of the fish has a lower potential for creating co-product as the round freezing does not lend itself to creation of waste streams. Some pelagic processors have moved away from 'round freezing' and this has created opportunities to consider co-product opportunities, however, there is no information available to suggest that offal and by-product has been directed towards co-product production.

Some sectors particularly finfish aquaculture have well developed and highly efficient value chains for by-products including viscera, heads and frames, the finfish sector has already well-established supply chain to feed by-products into and there appears to be little need for significant intervention in this supply chain.

Shellfish aquaculture provides a more complex picture with numerous operators of diverse scale, with production dispersed over a large area, it is also a sector with inconsistent, unpredictable volumes of by-product output and highly variable output (ranging from shells, mortalities, contaminated consignments, product recalls, etc.). The shellfish aquaculture and shellfish processing sector does not appear to be in a particularly favourable position to cost effectively enter the by-products market or even supplying materials to other providers for processing. It appears that the likelihood of significant volume of co-product from shellfish aquaculture entering the human food chain is highly unlikely. It appears more likely that operators will be directing by-product towards Category 1 and to some extent Category 2 waste management channels.

Irish fisheries present a more likely scenario for by-products entering the human food chain, there are some species with reasonable potential for exploitation, either through current under use in human food applications or through increased processing, value adding activities and subsequent generation of co-product and by-products. Some pelagic processors have slightly increased value adding activities in recent years (filleting and processing vs. bulk round freezing) and this has created opportunities for food grade co-product to be retained and reprocessed. Current efforts at quantifying by-product volume will likely bring the scale of the opportunity to direct co-products and by-products towards higher value applications.

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5. GUIDELINES FOR THE REGISTRATION OF BY-PRODUCTS

Finally, the analysis and test of the methodology conducted in each country (either region, sub-region or port) for the inventories of by-products and bycatch and industries' needs, enabled the project partners to establish guidelines aimed at public authorities regarding the registration of information of this kind of products.

Recommendations for guidelines aimed at public authorities regarding the registration of information on bycatch and by-products.

5.1. France

- The indirect method makes it possible to obtain data on the quantities of by-products available using the coefficient conversion from the France Agrimer report.

  ✧ We could determine the quantity per species at local, regional and national level with adjustment of landed volumes in relation to the corresponding year. But it would be relevant if the data were available on a regional level and not only on a national level.

  ✧A regular updating and verification of the coefficient conversion using a direct methodology will allow us to make these data reliable.

- The issue of access to data was critical. The difficulty of accessing reliable data not protected by statistical secrets jeopardizes the evaluation of the biomass volume of by-products and thus the research that could be conducted for better exploitation.

- There is also a need for better regulation of access to bycatch data for France, which could not be assessed during the project.

5.2. Spain

- Better accessibility to the information about registration of bycatch. The information was not easy to find through online research, not even by the correspondent public authority web/database.

- More detailed information about registration of bycatch. The information found was very scarce and limited. The logbook could also be shared publicly (previously filtered). Thus, registration of bycatch could be obtained classified by regions, species, fishing fleet, etc. This action would bring with it a more real estimation of bycatch.

- Although by-products' information belongs to private companies (aquaculture, seafood processing industries…), it could be of interest to create a general (anonymized) register/estimation of the amount of by-products, divided by sector (agriculture, aquaculture, etc.), to be aware of the global quantities every year (at national or regional level).

- A better awareness raising programme for the public authorities according to the possibilities of exploitation of bycatch and by-products. To make a point about the huge amount of these raw materials generated, the possibilities they offer to develop new human food products with high value added and all the benefits derived from these actions for companies, population, health, environmental, etc.

5.3. Portugal

- Survey and compilation of data from the aquaculture and processing industries, by the national authority – make data available.
- Development of the logistics channels for the processing companies – in Portugal, this logistics is complicated as it requires space and cooling systems.
- Promotion of R&D supporting units for processing companies.
- Work on the social acceptance of industry and consumers, about the negative weight of by-products re-use.

5.4. Ireland

- Significantly increased direct data collection on annual throughput/production of co-product and by-product, this should be done in cooperation with seafood industry and processing operators: [is >50% of the sector's volume by-product].
- Engagement with the processing sector should emphasize the need for self-reporting of by-product volumes from this sector to generate improved estimations.
- Specific studies should be carried out on the marine sector (seafood/seaweed) to generate highly accurate estimations of potential co-product volumes (human consumption) and by-product (non-human consumption) volumes.
- Methodologies to estimate co-product and by-product yields from standard seafood processing should be further developed to estimate product (fillet) yields and co-product arisings. This can strengthen estimates based on raw material volumes if co-product / by-product data is not collected.
- Increased engagement with the catching sector to understand the issues around reporting bycatch.
- Increased emphasis on convincing the processing sector to investigate the commercial opportunity, this will create better appreciation for the co-product and by-product opportunities and will enable the sector to view it differently and report better data. ***By-product and co-product may be perceived now as a problem and not an opportunity.***

6. NEEDS ANALYSIS FOCUS GROUP

Rationale for the Focus Groups.

Parallel to the inventory of biomass, a needs analysis of industry players in aquaculture and fisheries, through a collective workshop, will be established to identify capacities, bottlenecks and challenges for the development of the new products with a circular-economy approach.

In compliance with this objective, one focus group was organized in each country (4 focus groups in total), online or face to face, also involving the AQUAFISH0.0 partners in each territory.

The targeted members for the focus group were:

- companies that generate marine by-products,
- companies that valorise by-products,
- professional organisations,
- technical centres.

The Focus Group objective is to identify risks, challenges and needs of companies to valorise marine by-products.

6.1 France

Technopole Quimper Cornouaille organised an online focus group on October 1st, 2024 as a collaborative webinar.

Attendance sheet (Figure 28 and Table 22)

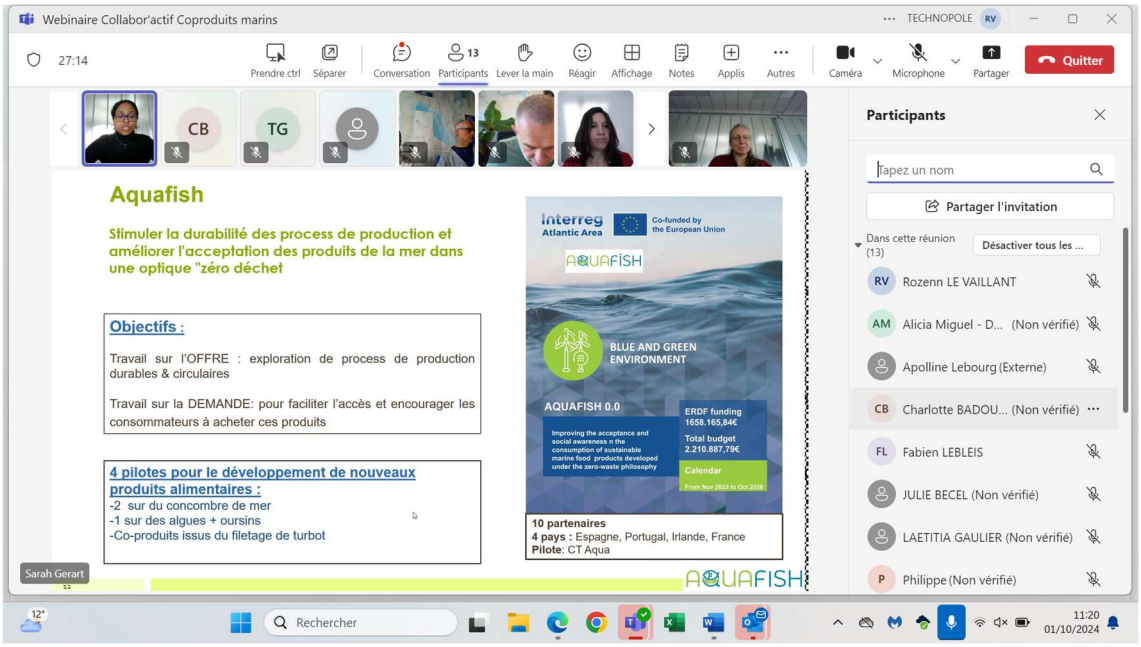

***Figure 28**: Screenshot of French Focus group.*

Attendees	Missing:
Technopole Quimper-Cornouaille **– Organiser**	CDPMEM29
Technopole Quimper-Cornouaille – Pôle Mer Bretagne Atlantique **- Organiser**	Institut Agro Rennes Angers
France AgriMer **- Speaker**	ABAPP
IDMER	
Pays de Morlaix – Blue Valley	
DGAMPA	
CRCBN	
CRCBS	
Ifremer	
Région Bretagne (x2)	
IUEM- LEMAR	
echnopole Quimper-Cornouaille – Valorial	

Table 22: *Participants.*

The Aquafish project and the framework of the focus group were presented to the participants – mainly coming from Brittany and involved with the valorization of marine coproducts, and belonging to professional organisations, Technical Centres, Research organisations, Regional authorities and Competitiveness clusters.

Introduction

Over the last 50 years, we have seen an increase in projects to recover by-products, particularly marine by-products, with more precise and restrictive regulations, but also with few incentives. Players are more committed to the environment, and manufacturers are tackling this issue by internalizing it or outsourcing it to other companies, with additional profitability and more profitable markets. In view of these developments and the various projects under way, the question arises as to the supply of raw materials. Are these resources under pressure or available in sufficient quantities?

We are in a changing context due to climate change, national public policies that are being implemented at regional level, and growing demand for these resources. The aim of the workshop is to address these issues and set them in a regional context.

The inventory of the blue bioeconomy in mainland France was drawn up as part of a FranceAgriMer study implemented by ACTeon (coordinator), Bureau Veritas, Euréka Mer and Ivamer. It is based on an analysis of existing data and literature, as well as interviews with players in the sectors concerned. The analysis was carried out for 2018, the most recent year for which all the data on landings, catches, aquaculture production and foreign trade were available.

The Blue Bioeconomy study published in 2021 by FranceAgriMer (Figure 29) applies a method for calculating the volumes of co-products based on (i) identifying the volumes produced for

each species of interest and (ii) applying processing coefficients in the marine production sectors. Recent developments in production and processing techniques need to be taken into account and require these input data to be regularly reviewed, so that the results of the study can be updated where appropriate. In order to carry out this update, the method applied in the 2021 study needs to be clarified, particularly with regard to the processing coefficients and volume calculations used, which presented inconsistencies and/or errors.

As a result of the updating work, a **simplified Excel file was produced for each species or sector**, France: containing the formulas to calculate the volumes of co-products generated by each processing stage. The Aquafish focus group provided FranceAgriMer with the opportunity to present the update and outline the biomass recovery circuit that applies in

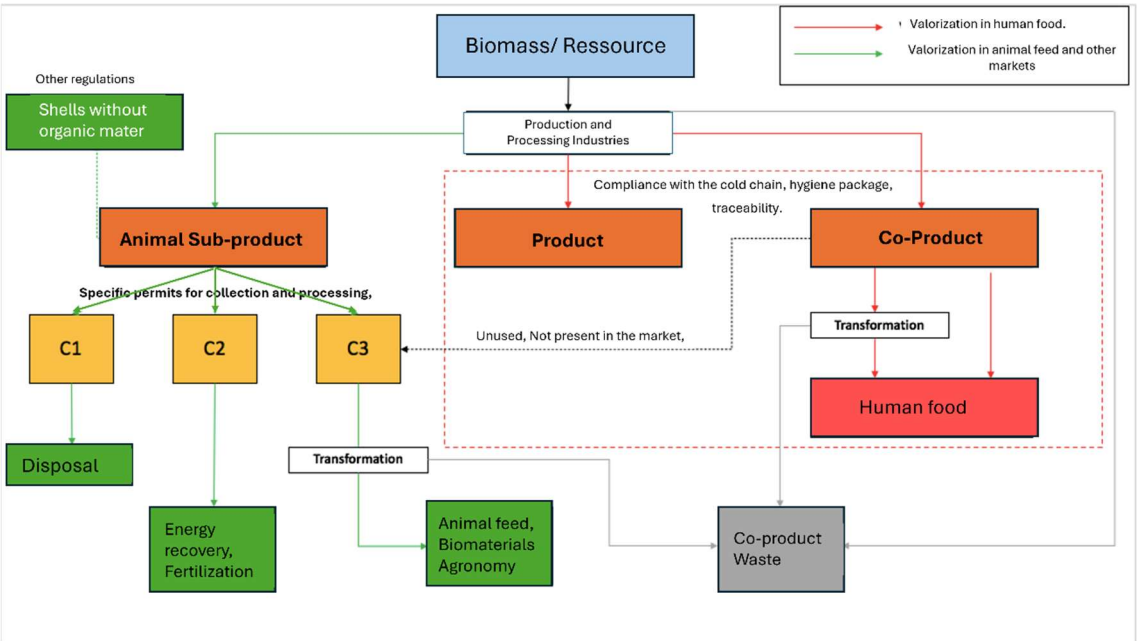

***Figure 29**: Slide presented by France AgriMer on the French value chain.*

An example was given of an update on one species: monkfish. The 2021 report published based on 2018 data stated that, for 21 650 tons of monkfish, 787,44 tons of co-products were created according to the initial 2021 coefficient (offcuts of viscera, heads, skins and dorsal spines). After checking the data and applying the new 2024 coefficients for the same quantity of monkfish landed, the volume of co-products is 10 387,25 tons. The updated report applying the new coefficients will be published in December 2024 or early 2025 for all species. However, they indicate that the problems of unsold fish and gutting on board remain, and that 100% of the fish caught are therefore considered to have been landed whole.

The issue of quantifying data is key to analysing the sector, promoting/supporting the development of new initiatives or optimising existing ones, and arbitrating on applications, but it remains a complex one.

After presenting the Aquafish project and the objectives of the various work packages, lessons learned from the 3 case studies carried out in Aquafish were presented to participants.

Several conclusions could be drawn:

Procurement is an important factor that must not be overlooked:

- ✓ A wide range of suppliers helps to optimise and secure supplies.
- ✓ Being able to work with frozen or salted raw materials and having plenty of storage space can help to overcome the problem of the impact of seasonality.
- ✓ The choice of raw material is essential: it can be dependent on weather conditions (rain, sun, etc.) (e.g. seaweed and shellfish) and its characteristics can vary over the year, impacting on processing (e.g. fat content of fish). The choice of species is important because the quantity and quality of co-products generated can vary.
- ✓ Concerns were raised about climate change (acidification, phytoplankton, etc.).
- ✓ There is also competitive pressure on the use of raw materials at different times of the year, driving prices up.

The use of raw materials presents a number of constraints:

- ✓ These raw materials can be fragile, which requires controlling numerous parameters
- ✓ Managing regulatory requirements: Traceability (internally or with suppliers) is a major issue to meet regulatory requirements. This requires rigorous monitoring and specific skills.
- ✓ The capacity to adapt to regulatory changes (new standards) is essential.
- ✓ Valorization processes are demanding and complex:
  - With a high degree of technical expertise (either in-house, requiring specific equipment, or outsourced, requiring a good choice of subcontractor).
  - They often consume energy, water…
  - A dedicated space is needed to develop the activity.

 Adding value to co-products often requires significant in-house R&D.

Finally, in terms of market issues, it appears that the market for fish co-products is more mature than that for seaweed or shellfish co-products in France. In addition, the social acceptability of using these raw materials in finished products is not obvious. To remedy this, BtoB marketing appears to be simpler than BtoC, especially as it is easier to convince a manufacturer than a consumer and requires fewer means of communication.

The second part of the focus group was an open discussion with all the participants, to gather their views on **the main problems and obstacles** currently affecting **the supply** of co-products to be recovered and valorized in Brittany. Several points were made, summarised below:

- ✓ Logistics is a key issue, as transport and collection have a significant impact on costs. The supply chain needs to be optimised.
- ✓ Regulations are particularly restrictive for food markets.
- ✓ Raw material prices are rising.
- ✓ The fragility and dispersal of fish by-products make it difficult to add value to them and to structure a supply chain.
- ✓ The development of high added-value products requires traceability requirements, sorting organisation, etc.

Their opinions were gathered on **the main lever/driver** they could identify today on the **supply of co-products** to be recovered in the Brittany Region. The following points emerged:

- ✓ Demand is growing, particularly for shellfish by-products.
- ✓ Adding value to by-products could be a way for producers to diversify in a context where their margins are squeezed. But they need support.
- ✓ There are many collaborative innovation initiatives in Brittany. R&D is needed in terms of outlets, applications and processes.
- ✓ Local authorities develop circular economy policies and incentives: for example, regional subsidies are increased if investments involve co-products (from the company's own production).

A round-table discussion was then held to gather their questions and comments following the previous discussion. The results were as follows:

- ✓ There is still the question of how to **share the value** throughout the chain, and what new business models to look for (e.g. fish wholesalers, whose margins are low).
- ✓ The **market for shellfish co-products** (particularly oysters) may be under pressure. Today, producers have generally found individual solutions for collecting their shellfish waste. In some areas, transport is free of charge in exchange for free co-products. Some valorization projects require extended supply from other regions: Normandy and Pays de Loire, for example.
- ✓ The **complex quantification of available resources**:
  ✧ For shellfish: a joint study by the 2 Breton regional shellfish committees to quantify volumes has been carried out. It must be noted that it is difficult to obtain data. Quantities leaving the farms are taken into account. There are large quantities of oyster shells on the consumer end of the market, but this volume is not measured, even though it is significant: it is important to organise this collection process in a complex way and to involve local authorities.
  ✧ There is no regional quantitative data. Possible reuse of FranceAgriMer conversion coefficients to calculate and obtain a regional estimate.
- ✓ **Questions about the impact of climate change**. It is **difficult to anticipate**, especially for fish: if we have less fishing volumes, there will be fewer co-products, so how can we ensure a sustainable supply?
- ✓ On the shellfish side, the COCORICO 2 and MITIC projects tackle this issue with an aim to select shellfish adapted to global warming and suggest protocols for mitigating these effects.

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- ✓ It seems easier to set up a shellfish co-products value chain because they are inert mono- products, compared with fish co-products.
- ✓ Consideration should also be given to the management of co-products that may result from co-products processing: **what about new waste generated after recovery/valorization** (e.g. algae & alginates)?

The following conclusions were drawn to the Aquafish Focus Group:

- ✓ Marine bioresources are a real asset for the Brittany region.
- ✓ Quantifying these resources remains an essential but complex issue. The Addendum to the FranceAgriMer study on the Assessment of aquatic biomass resources available in France co-products and by-products will be available by the end of 2024.
- ✓ Companies are increasingly interested in recovering by-products, either through their own internal management, by supplying potential resources, or by recovering biomass. There are initiatives in the region to organise the collection of certain types of waste, but this is still an obstacle. There is no structured sector yet. Matching resources and projects is not easy, as it is measured more on the scale of individual projects than on a value chain basis.

Looking Forward

A multi-criteria approach is needed to understand the value of marine by-products and the availability of resources.

In a study carried out in 2018 (*Reseda 2018 survey*), the motivating factors for companies' co-product recovery projects were as follows:

- Economic factor
- Product characteristics
- Regulatory aspects

It would be interesting to know whether this is still the case in 2024.
Finally, to carry out valorization projects, we need to think about the outlets, the valorization processes (the precise characterisation of co-products for optimum recovery), the supply and the valorization strategy (in partnership, internal or partial outsourcing).
The 3 determining factors in co-product availability are price, energy costs and climate change.

Studies of potentially available bioresources have been carried out in Normandy and the eastern part of France:

- ✧ 80% of recovered co-products came from less than 100km away. It would be interesting to know the existing flows in Brittany.

Several questions currently remain unanswered.

- ✓ There is still little overall view of both supplies and projects: What is the current state of the supply at regional level? How is it evolving?
- ✓ Predictive analysis: Can we forecast the use of co-products based on variables or pressures that are difficult to anticipate?

✓ Is there a hierarchy of uses or competition between uses? under which criteria? Competing uses: unlimited or constrained resources? For one resource, there may be several ways of recovery, and therefore several potential users, etc.

6.2 Spain

The focus group was carried out to obtain information on possible improvements in the use of fishery and aquaculture bycatch and by-products for human consumption, concretely: identify bottlenecks and potential uses, to obtain an economic return from them, business development opportunities and connecting projects with business initiatives. These actions will allow for the development of a common methodology to estimate the quantity and quality of bycatch and by-products in fisheries and aquaculture and to facilitate their management.

The focus group was carried out with the following participants (Figure 30):

- Sanlúcar Fisheries Association (auction and fishery).
- PETACA CHICO S.L. (seafood processing industry).
- Andalusian Marine Aquaculture Companies Association or ASEMA (aquaculture sector).
- Cádiz University or UCA (R+D sector).
- Agency for the management of agriculture and fisheries of Andalusia or AGAPA (administrative and regulatory sector).
- CTAQUA (intermediate between R+D and industrial sectors).

Figure 30. Screenshot of Spain Focus group.

Two main aspects were highlighted within the value chain of bycatch and by-products from fisheries and aquaculture:

- The access to databases about estimation of these raw materials in each step of the value chain.
- The management and application of these raw materials in each step of the value chain.

First of all, it is necessary to take into consideration that all steps included in the value chain are connected among them, depending on each other and conforming a very complex net.

Access to databases

Considering discards and bycatch from fisheries, data are public but not easily accessible. Databases about bycatch in autonomous communities are very limited because most vessels work far away from the coast and the competence then is on a national scale, i.e. the Spanish Ministry of Agriculture, Fisheries and Food (MAPA).

Databases about bycatch at national scale are only estimations and are not very complete and precise. In Spain there is an exemption for the landing obligation of bycatch (besides high survival species, which must be returned to the sea as soon as possible). It is called “minimis” and allows fishermen discard a 5 % of bycatch that are returned to the sea, while all the bycatch that exceed this 5% (of some target species and depending on the area) must be landed. All bycatch collected should be written down in the fishing notebook (DEA) but the reality is that the sector just registers less than 5% to avoid the landing obligation, causing an early gap of information and an underestimation of bycatch collected by the Spanish Ministry. Moreover, bycatch submitted to the landing obligation are discounted from the quota of the vessel, so fishermen try to not bring bycatch to port. The Spanish administration needs to propose solutions to facilitate the commitment and compliance of the landing obligation. Specifically, management and application of the bycatch volume that must be landed by this law as currently is not developed.

Respect to auctions and the first fish market, there are no bycatch because all catches that enter auctions are marketable species. On punctual occasions could be some determined species not sold (bycatch not by-products), but they are donated and the quantity is not enough to have databases or create a process of valorization.

In aquaculture, there are no bycatch or by-products because all specimens are sold. Those with small size, deformations and other anomalies are also sold at lower prices. Furthermore, since it is a controlled growth process, they are able to discard specimens before the fattening phase, being a minimal fraction (bycatch not by-products, independently if they are target species or not). Then, there are no databases about bycatch in aquaculture industries because it is not significant enough. Therefore, the production of discards/bycatch comes mostly from the extractive activity of fishing.

On the other hand, all the experts agreed that by-products (secondary raw materials from fish processing) come only from seafood processing industries. However, this information is confidential and belongs only to the private companies. Therefore, no databases exist in this sector.

Management and application

By-products are usually used for the same industry that generates them after a processing. This way, they could be revalorized in the company for human consumption through a transformation process or be destined to ABP companies (not for human consumption destination), such as pharmaceutical, cosmetic or feed industries. This sector is involved with

the R+D and the development of new food products for human consumption from fish by-products but they claim for more fundings to achieve this objective.

Bycatch is usually generated by fisheries (insignificant amounts from auctions or aquaculture industries). They could be destined for non-human consumption like ABPs companies or for human consumption, such as charity (through donations) or seafood processing industry (to transform them into new food products through a revalorization process). Focusing only on the human consumption destiny, there are some restrictions that limit the use of these bycatch.

Most charity entities do not have the suitable facilities to store high amounts of raw materials and most of them do not even have refrigeration or freezing chambers (needed for preservation of bycatch). Thus, they are currently not able to collect a significant quantity of bycatch. These charity entities would need specific fundings to change their infrastructure to be able to preserve bycatch.

Considering the seafood processing industries, in collaboration with R+D and technological centres, they could exploit bycatch, mainly from fisheries, to develop new food products for human consumption. However, they need some guarantees about correct management, transport, enough biomass, high quality, similarity among batches, consumer acceptability, etc. with bycatch to implement a new product in their production lines.

Bycatch is not the same in each port or vessel. They depend on the fishing area, seasonality, fishing gear, weather, etc. They could be even different from day to day for the same vessel. For this reason, there is an important variability on the collected bycatch but seafood processing industries require minimum variability in their raw materials. Then, the number of industries interested in bycatch is very limited. Besides, more studies about bycatch are needed by each specific region to obtain an exhaustive estimation of quantity and species of bycatch, establishing a database of bycatch per region, which can be consulted by seafood processing industries, guaranteeing always the access to their raw materials.

One of the crucial bottlenecks is the poor quality of landed bycatch. Since they do not have a market for human consumption and they are going to be destined for ABPs companies, mainly for feed industry where the quality is lower than for human food, fishermen do not treat bycatch as commercial species and the quality of them is strongly decreased. The easy solution would be treating bycatch as commercial species, so they could be used for human consumption (by processing industries) without health risks. Nevertheless, this effort is not currently profitable for fisheries due to different reasons: time, space, knowledge, quota, extra effort not remunerated, etc.

Bycatch are stored altogether on the vessel deck because the hold is reserved only for commercial species and there is not enough space for bycatch. Besides, commercial species and bycatch used to be separated because of differing quality and vessels do not have that infrastructure. Besides, fishermen have many tasks on board with commercial species and do not have enough time to attend bycatch. According to these inconveniences, they would need some consulting and fundings from the Ministry to adapt the infrastructure of vessels and to hire more crew members in charge of managing bycatch.

Sometimes they even do not have the sufficient knowledge to treat bycatch with the quality needed to be able to destine them to human consumption. This way, they also need training on fish quality, focusing on bycatch treatment.

Fishermen are sometimes reluctant to land bycatch because, as it was mentioned previously, they are considered for the quota, which means they can bring less quantity of commercial species and they will obtain less benefits. Hence, a modification of the law about quota related to bycatch would be necessary to prevent bycatch from affecting the quota of regular catch for commercial species and encourage the landing of bycatch. Moreover, fisheries need the guarantee that they will have enough processing industries interested in their bycatch.

All this bycatch should be correctly preserved until their use for the industry. The place for preservation could be in auctions, as intermediate between fisheries and industry. However, auctions do not have freezing chambers for human consumption of raw materials. So, they would need funding from the Ministry to achieve this objective. In addition, auctions would require a new legal authorization for this purpose.

All agents in the value chain are connected among them but each one is responsible for their specific tasks. For a correct management of bycatch with the proper quality some intermediate agents or companies are required, which will facilitate the transport or processing of bycatch, depending on the application they will have.

Finally, the processing industry needs a guarantee that their new products from bycatch are going to be sold. It depends on the acceptability of the products by consumers. Current consumers are a bit reluctant to acquire products elaborated with bycatch or by-products, probably due to the fear of a bad quality and the risk for health. Considering that the quality item is overcome from the previous point, a striking advertising campaign would be required about products based on bycatch and by-products to inform society about the benefits of consuming these kinds of products.

In conclusion, it can be said that there are several restrictions or limitations for all agents involved in the value chain of bycatch and by-products management and many actions are required, such as the following ones:

- Detailed studies about catalogues of bycatch for each region.
- Training for fishermen about management and quality of bycatch.
- Administrative support through consulting and funding for each agent involved.
- Consider the fisheries sector in the legislation process establishment with respect to the ways of facilitating the practical development of fishery labour.
- Create/improve logistics channels between fish markets and processing companies.
- Education of consumers about benefits and security of products based on bycatch and by-products.

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6.3 Portugal

Programme (Table 23 and Table 24)

Online : 16th October 2024, 14h-17h

14h30	Welcome and context of the Focus Group	Cátia Marques (Scientific Coordinator - S2AQUA)
14h40	Project AQUAFISH 0.0 overview	Alexandra Marques (Project Manager - S2AQUA)
14h50	By-products from the fishing and aquaculture sectors in Portugal – State of the Art	Lídia Nicolau (Training Coordinator - S2AQUA)
15h00	Innovative products based on pelagic species and by-products from fisheries: an opportunity for valorization	Ana Bispo (Reseacher – IPMA)
15h10	Challenges of a new generation of functional foods enriched with algae	Carlos Cardoso (Researcher - IPMA)
15h20	Q&A	
15h30	Brainstorming	
16h30	Discussion and conclusions	
17h00	Closing remarks	Cátia Marques (Scientific Coordinator – S2AQUA)

Table 23: *Portugal Focus group programme.*

Participants:

	Position	**Company or Institution**
1	Innovation and project manager	S2AQUA
2	Researcher	IPMA
3	Quality control technician	Ramirez & CA (Filhos) S.A.
4	Communication manager	S2AQUA
5	Principal researcher	ARDITI
6	Researcher	IPMA
7	Researcher	ARDITI
8	Scientific coordinator	S2AQUA
9	Post-doctoral researcher	IPMA
10	Head of quality and environment department	Flatlantic – Atividades Piscicolas S. A.
11	Training coordinator	S2AQUA

Table 24: *Attendance sheet.*

Within the framework of the AQUAFISH project, S2AQUA hosted an online Focus Group on October 16th 2024, with the aim of evaluating the current state of marine by-products management in Portugal. This workshop was attended by the Portuguese partners and by professionals from the aquaculture sector and from the fish processing industry (**Figure 31**).

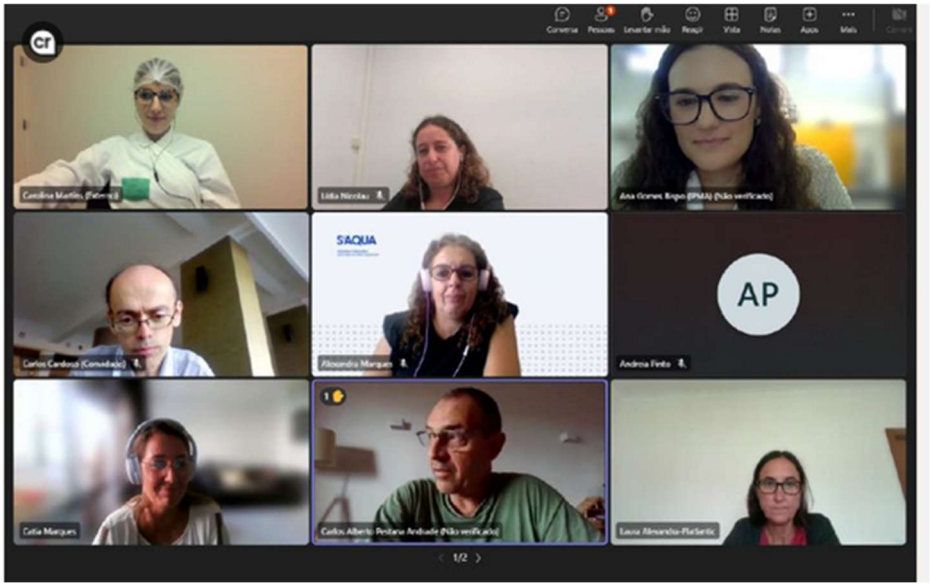

Figure 31. Screenshot of Portugal Focus group.

The focus group was a relevant opportunity to discuss marine by-products management, and the economic and logistical challenges faced. The first issue addressed was about is the volume of marine by-products produced in Portugal:

- Absence of data regarding by-products and bycatch from aquaculture and absence of data on the production of by-products from the transforming industry. This difficulty was also shared by the partner from Madeira Island.
- Reinforcement of the need to carry out an inventory of existing by-products and the quality of these by-products.

Therefore, the focus group addressed whether or not the quantities of by-products produced in Portugal are sufficient to enable the creation of new added value products:

- Everyone agreed that the quantities of by-products produced in Portugal are enough.
- There used to be three companies collecting and processing marine by-products, but recently one of those companies closed down, leaving a greater stress on the remaining two companies.

The last topic discussed was about the main constraints faced by the producers of by-products:

- The need for refrigeration to maintain the marine by-products category 3.
- The need for storage, since by-products are not collected on a daily basis.

6.4 Ireland

6.4.1 Seafood Innovation Network Workshop: Co-product Opportunities 12th November 2024

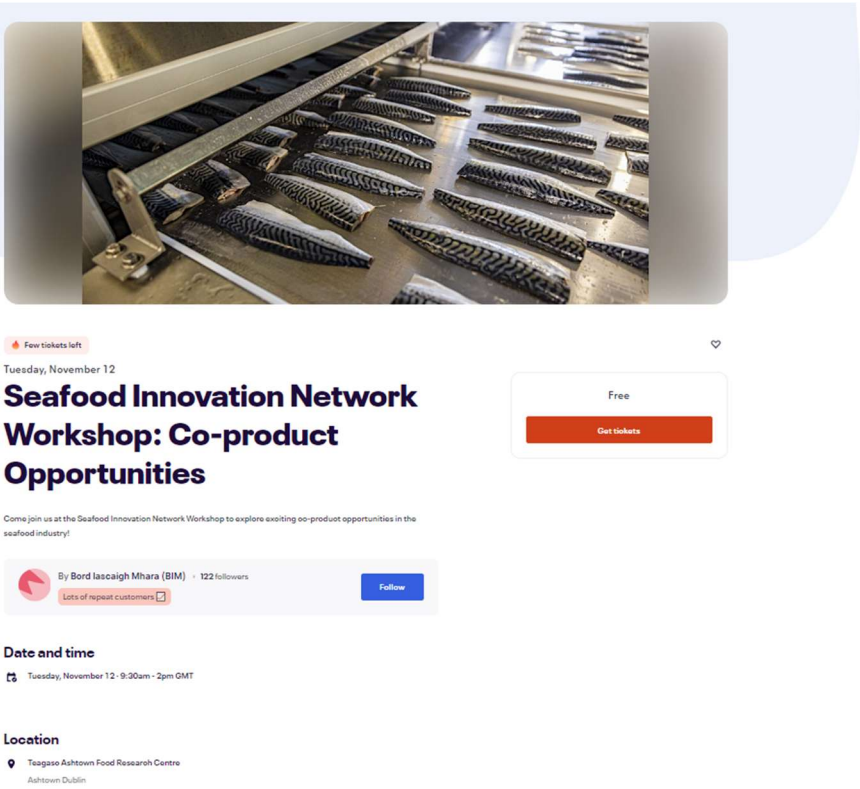

Figure 32: *Screenshot of Eventbrite booking page for Seafood Innovation Network event.*

BIM in partnership with Teagasc held its second ***Seafood Innovation Network*** event on Seafood Co-product opportunities on the 12th November 2024 in Teagasc, Ashtown Food Research Centre, Dublin 15 (Figure 32).

The event brought together Irish and International processing and co-product experts, seafood industry operators, research providers, development agencies, government officials and other stakeholders.

A proposed series of focus groups for the event were cancelled on the day of the event due to time constraints. The presentations of the workshop (Figure 33-Figure 39), combined with some industry interviews are provided in place of a dedicated focus group.

During 2022 and 2023 Irish processors invested over €70 million in processing technologies with support from BIM's Brexit Processing Capital Support Scheme, which demonstrates a willingness and capacity to diversify. As a result of these investments value-add processing activities have increased, meaning significant volumes of previously unavailable co-products have come on stream to enable further value extraction. Opportunities exist particularly for human ingredients and non-ingredient markets, and to derive more value from commercial and under-utilised species.

This event was developed to showcase the co-product opportunities available to Irish seafood processors, highlighting the importance of circularity and the ongoing national and international commercially focused initiatives in this area. Commercial case studies of utilisation of co-products and input from regulatory bodies were also discussed.

The workshop succeeded in delivering some interesting and relevant findings that relate to the project, initial findings of a study being undertaken jointly by BIM and a study in partnership with Upcyclink indicated that there are opportunities and obstacles to the development of co-product processing in Ireland.

Frédérick Mens from Upcyclink, (France) gave an interesting perspective on the status of co-product and by-product processing in Ireland.

Upcyclink, working on behalf of BIM contacted a number of seafood processors during 2023 / 2024 with a view to getting feedback on co-product processing, the feedback is summarized in Figure 12., it appears that the sector is highly competitive in terms of raw material sourcing and business, however, collaboration appears possible, which could be critical to overcoming issues with scale and raw materials.

There is interest in valorization but a lack of knowledge appears to be the main impediment to action. Technical and market knowledge appears to be inadequate at present and action may be required in these areas.

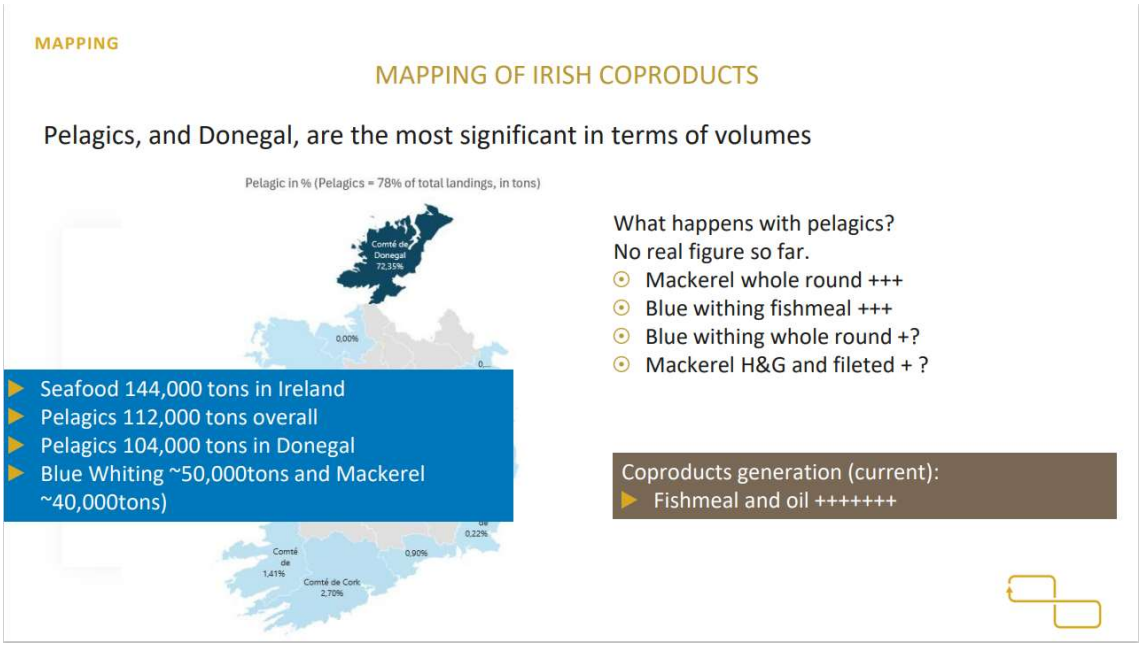

***Figure 33**: Slide from Presentation by Frédéric Mens, Upcyclink at SIN event 12th November.*

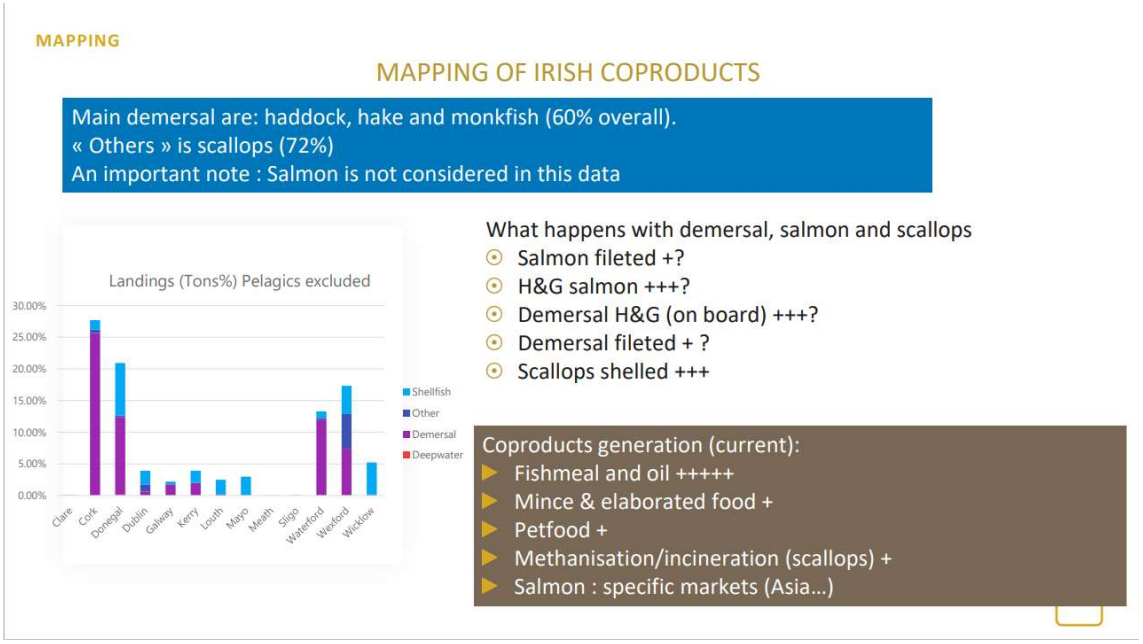

Figure 34: *Slide from Presentation by Frédéric Mens, Upcyclink at SIN event 12th November.*

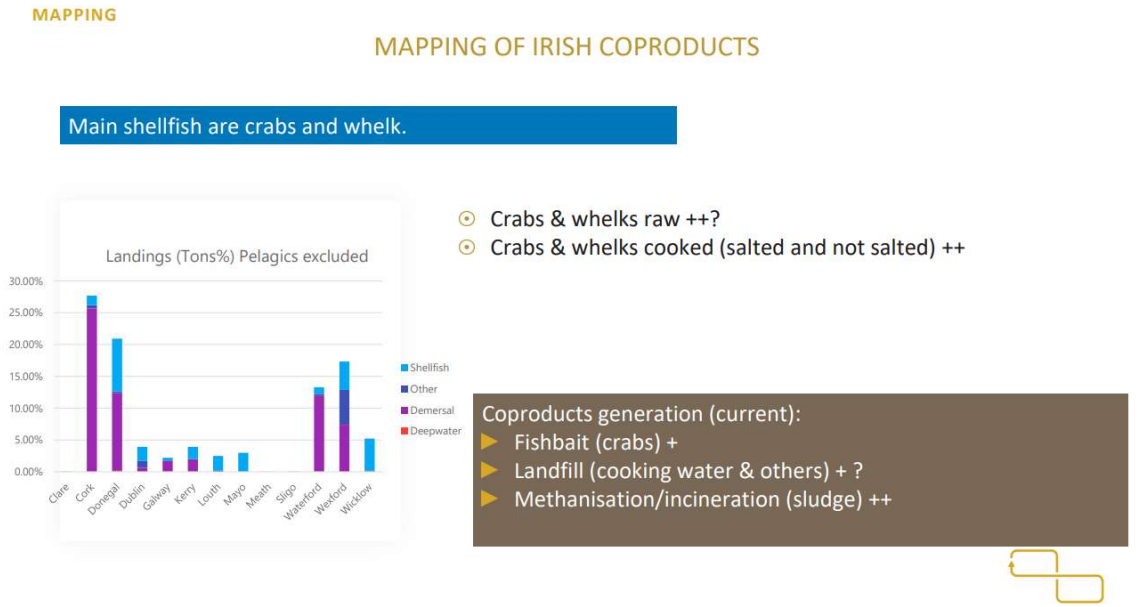

Figure 35: *Slide from Presentation by Frédéric Mens, Upcyclink at SIN event 12th November.*

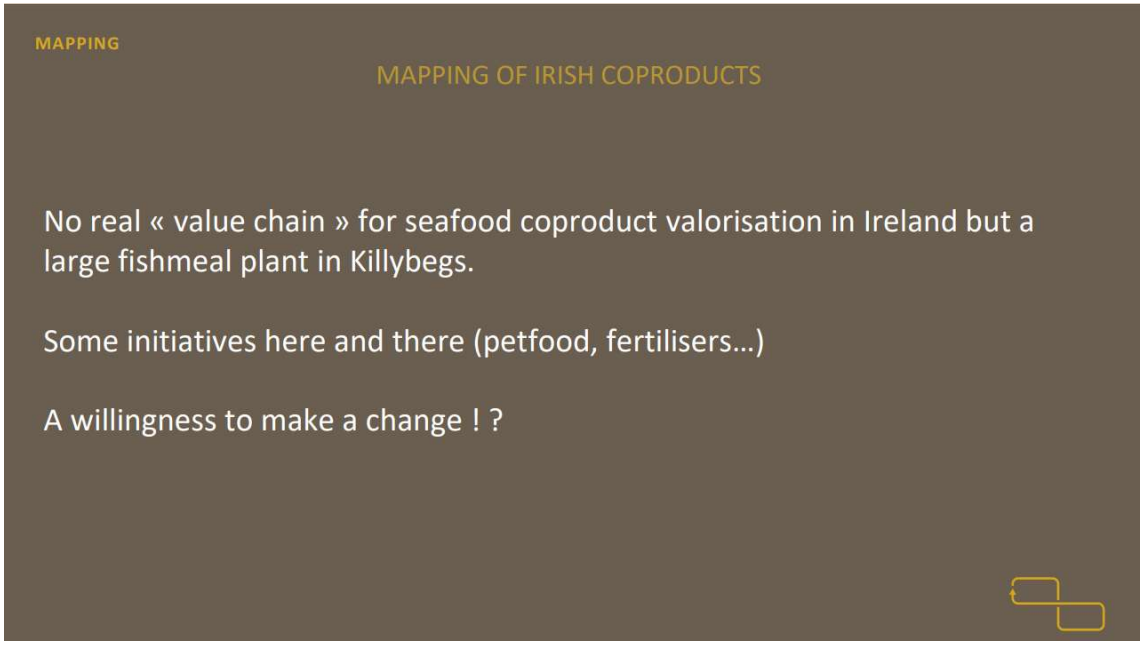

***Figure 36**: Slide from Presentation by Frédéric Mens, Upcyclink at SIN event 12th November.*

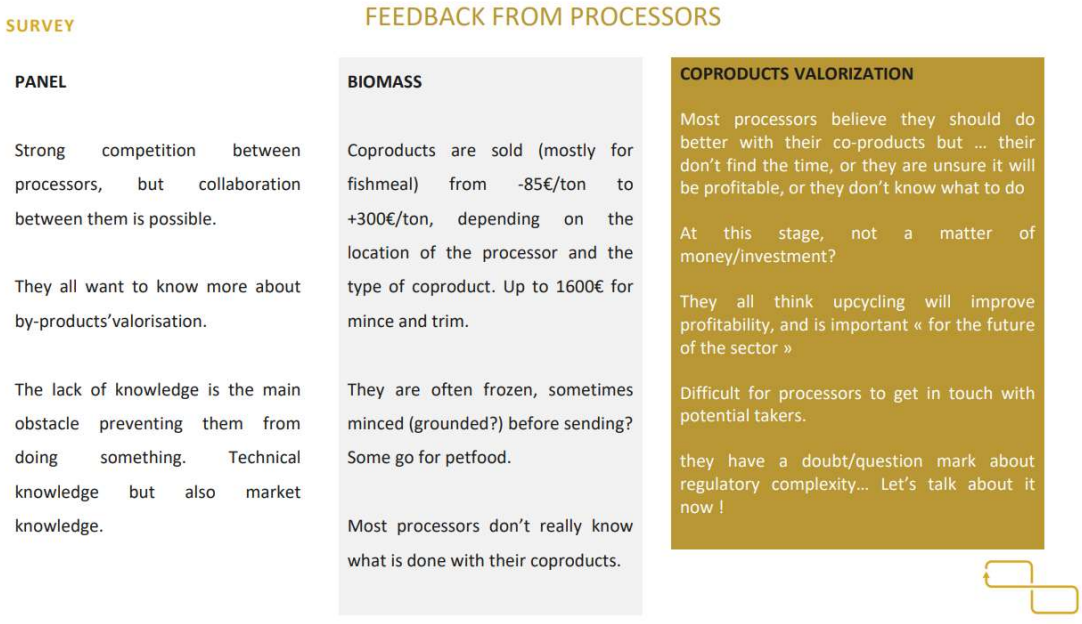

***Figure 37:** Slide from Presentation by Frédéric Mens, Upcyclink at SIN event 12th November.*

***Figure 38**: Mr Shay Hannon of Teagasc (Right) addressing attendees of the Seafood Innovation Network Workshop: Co-product Opportunities 12th November 2024. An overview and demonstration of technology was provided.*

Seafood Innovation Network event - Co-Product opportunities
12 November, Teagasc Ashtown
Agenda

10:00am	Introduction & BIM Co-product outlook	Michael Gallagher, **BIM**
10:15am	The Irish Seafood Co-Product landscape & opportunities	Jean-Pascal BERGÉ & Frédéric Mens, **Upcyclink**
11:00am	Commercial Case Study	Emmanuel Boucher, **Copalis**
11:20am	**Tea & Coffee Break**	
11:45am	Case Study- Commercializing Co-Products	Greg Devlin **Silver Hill Duck**
12:05pm	Enabling Co-Products through Innovative Equipment Superground	Santtu Vekkeli, Founder, **Superground**
12:25pm	**Guided Discussion**	
12:55pm	Closing Remarks	Michael Gallagher, **BIM**
13:00pm	Overview & Demonstration of Technology	Shay Hannon, **Teagasc**

***Figure 39:** Agenda of Seafood Innovation Network Workshop: Co-product Opportunities 12th November 2024.*

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Interview 1. Andrew Keady, Director and Plant Manager, Galway Bay Seafoods, Galway.

Galway Bay Seafoods are a Galway city based seafood processor. The company buys, processes and sells a wide variety of fresh, processed and frozen seafoods. The company supplies 80% of their output to Food Service outlets and 20% to retail operations, with retail sales growing in recent years. The company operates a number of fish shops in the Galway area. The company would be broadly representative of a medium sized fish wholesaler / retailer in Ireland.

The bulk of their purchases and sales are comprised of Salmon (*Salmo salar*) and White fish such as Cod (*Gadus morhua*), Hake (*Merluccius merluccius*) and other mixed white-fish) the company purchases approximately 12 tons of white fish monthly and 10 tons of Salmon monthly. The company also purchases and sells 4 tons of shellfish on a monthly basis (Prawns, *Nephrops norvegicus;* Crab, *Cancer pagurus;* Lobster, *Hommarus gammarus*; and others).

Product	Inputs (Monthly/kgs)	Typical yields %	By-product %	By-product utilization
Salmon	8 000 - 10 000	70-72	28-30	No. sold fish meal producer.
Cod	3 500	45-50	50-55	No. sold as fishing bait
Hake	4 500	40-50	50-60	No. sold as fishing bait
Whitefish (other)	4 000	50	50	No. sold as fishing bait
Shellfish (various)	4 000	>95	<5	No. sold live or whole

***Table 25**: Estimates of Yield and co-product generation at Galway Bay Seafoods (2024).*

The company usually purchases fresh, Irish landed fish for processing, the company usually takes delivery of eviscerated but otherwise whole fish. Filleting is done by hand and yields achieved are usually quite high compared to machine filleting. The by-products (Table 25) produced (heads, frames, tails, trimmings and rejects) are usually consolidated into 20 kg fish boxes and sold to local fishers for a nominal charge.

Salmon by-product, which cannot be provided to fishers for bait, is usually consolidated, frozen and provided to a fishmeal producer for further processing.

Shellfish processing is limited and generates no or very low levels of by-product.

Mr Keady indicated that difficulties with recruitment of adequate numbers of staff, a shortage of specialised skills (filleting) and energy management initiatives (using smaller capacity freezer stores) were all presenting obstacles to potential efforts to recover or add value to co-product from filleting and processing. Mr Keady indicated that rapid sale of by-products to keep freezer space utilized to a minimum were important practical operational matters.

6.4.2. Casting a wider net – highlighting potential of underused species.

Members of Ireland's fishing sector, seafood processors and retailers gathered in Waterford during October 2024 at an event showcasing the potential of Ray (Raja spp.), Rock Salmon / Spur dog (*Squalus acanthias*) and Red Gurnard (*Chelidonichthys cuculus*).

BIM and the Irish South and East Fish Producers Organisation hosted the industry event at Grow HQ (Figure 40), an organic café in Waterford city pioneering a sustainable food system, with much of the food it serves grown on site. Grow HQ chef, JB Dubois created a sample of dishes for industry attending the event including fish cakes made with rock salmon, cured gurnard gravadlax, ray bouillabaisse, pan roast gurnard tandoori and fish pie made with ray.

The event included presentations by the Marine Institute outlining the most recent scientific assessments of the species. Fish processing technology maker, Steen also gave a short talk on processing technologies and equipment for these species. Brendan Leonard, fisherman and vessel owner, MFV Caronia II and Irish South and East Fish Producers Organisation Director welcomed the event describing it as a "first step in the journey".

Figure 40: *Pictured left to right: Vincent Ryan, Domestic Market Development Executive, BIM, Brendan Leonard, Director Irish South and East Fish Producer Organisation, JB Dubois, Chef and Head of Food, Grow H*

7. CONCLUSIONS

The objectives of this study were:

- to estimate the volumes of by-products and bycatch available in each country to assess their valorization potential.
- -explore existing methodology framework in each country to estimate available marine biomass

Several observations were made:

- There is a need to define what constitutes a by-product, co-product and sub-product as this definition can vary from one country to another and depends on the specific use of these terms.
- Difficulties in accessing data were highlighted for the four countries. Indeed, very little data is publicly available or accessible even upon request.
- Initiatives for the valorization of marine by-products exist in each country, but they are mainly directed towards animal feed and, to a lesser extent, human food at the moment.

From a circular economy perspective, it seems essential for each country to establish competent organisations to monitor and publicly share data on the volumes of marine by-products available at both national and regional levels. This is the only way for businesses to innovate, to envision and develop a viable business model for the valorization of these co-products.

8. REFERENCES

8.1 France

Alain Biseau (RBE), "Diagnostic 2 0 2 2 sur les ressources halieutiques débarquées par la pêche française hexagonale". peche.ifremer.fr. WEB. Janvier 2023

Agreste, 2024. *Enquête aquaculture 2022*. Agreste, 68 p.

Andrieux G., 2004. *La filière française des co-produits de la pêche et de l'aquaculture : état des lieux et analyse*. Ifremer, 1-59 p.

Association Française Halieutique, 2018. *Obligation de débarquement : évitons l'échec.*

Bergé, J.P., 2008. Added Value to Fisheries Wastes. Research Sign post. India publishers.

Bogart S., 2024. *SankeyMATIC: Build a Sankey Diagram*. https://sankeymatic.com/build/ (Consulté le 29 juin 2024).

Cloatre Thomas, Scavinner Marion, Sagan Jonathan, Dubroca Laurent, Billet Norbert (2022). Captures et rejets des métiers de pêche français. Résultats des observations à bord des navires de pêche professionnelle en 2020. ObsMer. ObsMer. https://doi.org/10.13155/88406

Comité National de la Conchyliculture, **CIPA**, et **Régions de France**, 2022. *Plan Aquacultures d'avenir 2021-2027*. 87 p.

Commission Européenne, 2020. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions a New Circular Economy Action Plan for a Cleaner and More Competitive Europe*.

Conseil européen et **Conseil de l'Union Européenne**, 2024. *Pacte vert pour l'Europe*. https://www.consilium.europa.eu/fr/policies/green-deal/ (Consulté le 7 mai 2024).

CRPMEM Bretagne, 2023. *Analyse des données déclaratives de récolte des algues de rive - Programme Agrid (2019 – 2022)*. CRPMEM Bretagne, 45 p.

"Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives". eur-lex.europa.eu. WEB. 18/02/2024

Dumay J., 2006. *Extraction de lipides en voie aqueuse par bioréacteur enzymatique combiné à l'ultrafiltration : application à la valorisation de co-produits de poisson (Sardina pilchardus)*. (Thèse de doctorat). Nantes. https://theses.fr/2006NANT2057

FAO, 2022. *La situation mondiale des pêches et de l'aquaculture 2022*. Rome : FAO, 294 p. ISBN 978-92-5-136461-1

"Feuille de route Nationale pour le Développement des filières algales française". Mer.gouv.fr. WEB. Février 2024

FranceAgriMer, 2022. *Chiffres-clés des filières pêche et aquaculture en France en 2022*. FranceAgriMer, 40 p.

FranceAgriMer, 2023a. *Chiffres-clés des filières pêche et aquaculture en France en 2023*. FranceAgriMer, 40 p.

FranceAgriMer, 2023b. *Commerce extérieur des produits de la pêche et de l'aquaculture - Données 2022*. FranceAgriMer, 116 p.

FranceAgriMer, 2023c. *Consommation des produits de la pêche et de l'aquaculture - 2022*. FranceAgriMer, 133 p.

FranceAgriMer, 2024. *Données de vente déclarées en halles à marée en 2023* - BIL-MER-VENTES-HAM-A23, FranceAgriMer, 100 p.

FranceAgriMer, 2024b. *Évaluation et suivi de la contribution sociale et économique de la filière des macroalgues*. Montreuil : FranceAgriMer, 20 p.

FranceAgriMer, 2023d. *Souveraineté alimentaire : un éclairage par les indicateurs de bilan*. Montreuil : FranceAgriMer, 158 p.

FranceAgriMer, **Strosser P.**, **Zaiter Y.**, **Bernard I.**, **Estelle L.B.**, **Renaud C.**, **Olsommer M.**, et **Lacombe S.**, 2021a. *Évaluation des ressources en biomasse aquatique disponibles en France – coproduits et sous-produits* (Volume I). FranceAgriMer, 75 p.

FranceAgriMer, **Strosser P.**, **Zaiter Y.**, **Bernard I.**, **Estelle L.B.**, **Renaud C.**, **Olsommer M.**, et **Lacombe S.**, 2021b. *Évaluation des ressources en biomasse aquatique disponibles en France – coproduits et sous-produits* (Volume II). FranceAgriMer, 234 p.

Ifremer, 2022. *France métropolitaine. 2020. Synthèse de la flotte.* Ifremer, 10 p.

Ifremer, 2024. *Région Bretagne. 2022. Activité des navires de pêche.* Ifremer, 13 p.

Le Bras, Q., L. Ritter, D. Fasquel, M. Lesueur, S. Lucas, et S. Gouin, 2014**.** "Etude de la consommation des algues alimentaires en France. Programme IDEALG Phase 1. Etude nationale." Les publications du Pôle halieutique AGROCAMPUS OUEST n°35, 72 p.

Marieux R., 2022. *ALGRIPLAST – Valorisation de dérivés et coproduits d'algues – NATUREPLAST*, https://natureplast.eu/algriplast-valorisation-de-derives-et-coproduits/ (Consulté le 23 août 2024).

Parlement Européen et **Conseil de l'Union Européenne**, 2013. *Règlement (UE) n ° 1380/2013 du Parlement européen et du Conseil du 11 décembre 2013 relatif à la politique commune de la pêche, modifiant les règlements (CE) n ° 1954/2003 et (CE) n ° 1224/2009 du Conseil et abrogeant les règlements (CE) n ° 2371/2002 et (CE) n ° 639/2004 du Conseil et la décision 2004/585/CE du Conseil*. http://data.europa.eu/eli/reg/2013/1380/oj/fra

Penven A., 2014. *La gestion des ressources et des territoires : application à la mise en oeuvre de projets de valorisation de sous-produits de poisson*. (Thèse de doctorat). Nantes : Université de Nantes. https://theses.fr/2014NANT2027

PETR du Pays de St Malo, 2024. *Etude, conception et installation d'un pilote pré-industriel de méthanisation de sous-produits conch*. http://www.pays-stmalo.fr/methanisation-des-sous-produits-concylicoles-C246.html (Consulté le 23 août 2024).

Port de France. WEB. Port.fr. https://www.port.fr/membre/chambres-de-commerces-et-dindustrie-et-autres-etablissements-gestionnaires-de-port/cci-2

SemBreizh, 2023. *Avec #Kerbone, BreizhImmo s'investit au côté du Groupe Mytilimer: Sembreizh*. https://www.sembreizh.fr/actualites/detail-d-une-actualite/avec-kerbone-breizhimmo-s-investit-au-cote-du-groupe-mytilimer.html (2 août 2024).

Steeve Constant, "La face invisible de la pêche : les prises accessoires". france3-regions.francetvinfo.fr. WEB. 05/09/2023.

Syndicat mixte des ports de pêche-plaisance de Cornouaille. "Bilan d'activité 2023, pêche et plaisance de Cornouaille". 2023

Union Européenne, 2023a. *Économie circulaire : définition, importance et bénéfices*. https://www.europarl.europa.eu/topics/fr/article/20151201STO05603/economie-circulaire-definition-importance-et-benefices (Consulté le 26 février 2024).

Union Européenne, 2023b. *Sous-produits animaux non destinés à la consommation humaine | EUR-Lex*. https://eur-lex.europa.eu/FR/legal-content/summary/animal-by-products-not-intended-for-human-consumption.html (Consulté le 26 février 2024).

VIZAGRESTE, 2021. "L'aquaculture". WEB: https://vizagreste.agriculture.gouv.fr/aquaculture.html

8.2 Spain

Iñarra, B., Bald, C., San Martín, D., Orive, M., Cebrián, M. y Zufía, J. (2018). Guía para la valorización de subproductos de la acuicultura. *AZTI*. Derio, Spain. 44 pages.

Cabrera-Castro, R., Macías, F. y García-Rodríguez, C. (2020). ECOFISH: Informe Equipo Descartes. Puerto Real, Spain.

Cabrera-Castro, R. y García-Rodríguez, C. (2021). ECOFISH: Informe Equipo Descartes (Proyecto Ecofish 2). Puerto Real, Spain.

European Union. (2009). Regulation (EC) No 1069/2009 of the European Parliament and of the Council, of 21 October 2009, laying down health rules as regards animal by-products and derived products not intended for human consumption. *Official Journal of the European Union*, 2009R1069, 01-64.

European Union. (2013). Regulation (EU) No 1380/2013 of the European Parliament and of the Council, of 11 December 2013, on the Common Fisheries Policy. *Official Journal of the European Union*, L354, 22-61.

MAPA. (2023). Estadísticas Pesqueras: Capturas de Pesca Marítima. Madrid, Spain.

Valeiras, J. (2015). Los descartes pesqueros: causas y medidas de reducción. *Ambienta,* 111, 18-31.

8.3 Portugal

INE, I. N. (2010-2023). *Estatísticas da Pesca.* INE. Lisbon: INE

Nunes, M. L. (2012). "Valorização de rejeições e subprodutos do processamento de pescado.

Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation).

Sotelo, C.; Maguire, J.; Batista, I.; Borseau, P.; Guérard, F.; Floch-Laizet, C. (2011). *Marine Bbiomasses of the Atlantic Region.* BIOTECMAR.

8.4 Ireland

Attard, J., & O' Conner, T, 2022. Food Loss and Waste from Farming, Fishing and Aquaculture in Ireland, EPA Report No.410.

BIM, "The Business of Seafood". Bim.ie. WEB. 2023.

Eurostat. 2022 Statistics.

Clean Technology Centre, Circular Bioeconomy Research Group, MTU, and Benton Ecological Solutions and Technology, "Socioeconomic Study of Seaweed Harvesting Along the West Coast of Ireland," Marine Institute, 2022. [Online].
Available: https://emff.marine.ie/blue-growth/socioeconomic-study-seaweed-harvesting-along-west-coast-ireland.

Dominguez *et al*, 2024. Fish Viscera Hydrolysates and Their use as Biostimulants for Plants as an Approach towards Circular Economy: A Review.

Giron-Dominguez., G and Gaffey., J. 2024. D2.2 Quantification of Biological Raw Materials for Ireland's Bioeconomy CHAPTER 4 MARINE BIOMASS ARISINGS [Online]. Available: https://informbioproject.ie/project-outputs/.

Pfeiffer, N. "Disposal and Re-utilisation of Fish and Fish Processing Waste (including Aquaculture Wastes)", NDP Marine RTDI Desk Study Series, Marine Institute 2003.

SFPA Annual Statistics 2023