Global at-sea fish processing
A review of current practice, and estimates of the potential volume of by-products and their nutritional contribution from at-sea processing operations

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Summary

Seafood consumption has a key role in global protein intake and broader human nutritional needs. This is directly, through consumption of seafood products, and indirectly, through its use in the animal feed chain to help produce additional food sources. However, 30% to 35% of the fish caught is either lost or wasted along the supply chain (FAO, 2020). A proportion of this includes losses through at-sea processing of fish and shellfish.

Global catch of fish and shellfish is 108 million tonnes (live weight). For the purposes of this report, the primary species groups identified as most likely to be processed at sea are demersal species, pelagic species (tunas, bonitos and billfish), and shellfish (squid). It is also assumed that the majority of other pelagic and shellfish species are less likely to be processed at sea (albeit there are exceptions).

Numerous species of fish and shellfish will undergo some form of processing (product transformation) at sea. This can be undertaken by varied sizes and types of fishing vessel, using an array of fishing gears to target the catch. There are variations on all these practices within countries, regions and globally. Data on all these areas are limited and it is only possible to provide general indications.

Vessels >24 m length overall (LOA) are most likely to be engaged in some degree of processing-at-sea operations. There are almost 68,000 vessels globally >24 m LOA. The majority (nearly 80%) of these are registered in flag states in Asia. The lack of data means it is challenging to provide any exact figures for these 68,000 vessels to show types of on-board processing facilities, extent of processing, exact weight of capture etc.

Diverse types of fishing gear will be used by vessels undertaking processing at sea. The most typical gear types include trawls, longline, purse seine, and jiggers (squid).

Published data on the global production of by-products produced at sea is not available. Therefore estimates based on global catch and by-product yields are provided in this report. Applying a series of assumptions and ranges provides a very broad estimate of by-products at sea. This is calculated as 1.5 to 25 million tonnes, globally. This huge range in quantities takes into account the lack of data and evidence, the fact that not all species are processed at sea, and that the extent of processing at sea varies within a species, in a country, between countries and globally.

The extent and type of processing is driven by several factors. Quality and hygiene requires guts (viscera) to be removed from demersal fish, to maximise shelf life. Market requirements for products are key drivers, for example frozen-at-sea products such as headed and gutted fish or fillets are produced to satisfy specific on-shore market requirements.

Larger ‘factory’ vessels, with fully automated processing lines on board, are more likely to retain by-products. By-products are retained for various reasons including direct human consumption markets (e.g. cheeks), further processing (e.g. skins for collagen), or introduction into the marine ingredients supply chain (fishmeal and fish oil). All of these are vital outlets for by-products.

There are numerous reasons why more by-products are not retained on board. They include lack of space/capacity on the vessels, lack of time to process, no/low demand, and low market value. It will take a significant shift in the market and value of by-products to change this current situation.

There are major vessels, types of vessels and nations that have become very successful at maximising the use of the catch. In these examples, vessels processing and freezing at sea retain a considerable quantity of by-products for different uses. Iceland has spent 30 years investing and innovating in by-products and, through collaboration, is able to maximise the use of a valuable species (cod). In the past 20 years, the Alaska pollock sector in the US has shifted attention from ‘maximise volume of catch’ to ‘maximise utilisation of catch’. Catcher-processing-freezer vessels can now demonstrate full catch utilisation, with investment in on-board processing equipment and fishmeal production.

While there would be advantages to accessing and utilising more at-sea by-products, for both direct consumption and indirect consumption, this cannot be looked at in isolation. Other factors that should be taken into consideration include the impact on marine habitats and the ecosystem, implications for crew work, earnings, safety, catch handling/safety/storage, vessel infrastructure etc. This is before consideration of access to sustained outlets or markets that will suitably recompense fishers.

There are data and knowledge gaps to address in considering the potential for increased utilisation of global at-sea by-products. It is evident there are differences between species, vessels and flag states and this is not a ‘one size fits all’ challenge. However, with collaboration and investment in technology, infrastructure and markets, access to at-sea by-products could provide a way to maximise the use and value of the global catch of fish and shellfish.
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### Acknowledgements
1. Introduction, definitions, and context

The responsible production of food is vital to nourish the world’s population. In addition, ensuring efficiency in food systems is critical to ensure the maximum nutrition is derived from the food we produce.

Food loss and waste is an issue of global concern. The 2030 Agenda for Sustainable Development reflects the increased global awareness of the problem. Target 12 of the United Nations’ Sustainable Development Goals (United Nations, 2020) calls for sustainable consumption and production patterns, which includes maximizing the use of food sources.

Seafood is an extremely valuable commodity, and it is vital to maximize the use of the global wild catch and aquaculture production. Seafood consumption plays an important role in global protein intake and broader human nutritional needs. This is directly, through consumption of seafood products, and indirectly, through its use in the animal feed chain to help produce additional food sources.

However, 30% to 35% of the fish caught is either lost or wasted along the supply chain (FAO, 2020). A proportion of this includes losses through at-sea processing of fish and shellfish. The volume of material that is removed from processing fish at sea could be a vital source of nutrition if it is possible to bring it ashore for utilization.

This report aims to:

- Provide an overview of processing of seafood at sea to understanding current levels of loss (volume and nutrition).
- Better understand by-products that are retained and utilized by some vessels.
- Summarise the challenges for greater by-product retention, including identifying current knowledge gaps.

1.1. Understanding seafood processing at sea and by-products

After capture, some species of fish and shellfish may undergo some form of processing (product transformation) at sea. The extent of any processing at sea varies depending on the species, product format, market requirements (local, national, global), size of fish, value of by-products, availability of markets for by-products, on-board facilities, vessel sophistication etc.

The main activities that comprise processing at sea are detailed in Table 1.

<table>
<thead>
<tr>
<th>Processing activities</th>
<th>Components removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evisceration (gutting)</td>
<td>Removal of viscera, including liver and reproductive organs</td>
</tr>
<tr>
<td>De-heading</td>
<td>Removal of the head</td>
</tr>
<tr>
<td>Skinning</td>
<td>Removal of the skin</td>
</tr>
<tr>
<td>Filleting (or portion creation)</td>
<td>Production of the main part of edible flesh in a preferred format (e.g. fillet, block, steak)</td>
</tr>
<tr>
<td>Trimming (cutting fins and belly flaps)</td>
<td>Typically in conjunction with filleting, for trimming winter or wholly processed products</td>
</tr>
<tr>
<td>Gill removal</td>
<td>Gills</td>
</tr>
<tr>
<td>Shellfish processing</td>
<td>Typically only for crustaceans and cephalopods</td>
</tr>
<tr>
<td>Freezing</td>
<td>Technically classed as processing, does not in itself create by-products but can alter net weight of landed product e.g. drip loss on thawing</td>
</tr>
</tbody>
</table>

1.2. Understanding by-products from seafood processing

For the purposes of this report, at-sea by-products are defined as:

- The residual parts of fish and shellfish remaining after removal or separation of the main edible portion, and
- Removed from the whole animal at sea.

Table 2 provides a list of by-products from fish and shellfish.

What constitutes a by-product varies depending on many factors; a by-product in one region may be a product for direct human consumption in another region, e.g. fish heads.

The term by-product does have alternative terminology depending on the region, the species and the point in the supply chain. For example, other terms include processing waste, rest raw material, co-products, offal, and trimmings.

1.3. Understanding fishing vessels

Fishing vessels can be broadly classed into three categories (MarineInsight, 2022):

- Commercial fishing vessels
- Artisanal fishing vessels
- Recreational fishing vessels.

This report is only concerned with commercial fishing vessels, used for catching fish and other seafood from wild fisheries for commercial profit.

Two size descriptors for fishing vessels are commonly used:

- Length overall (LOA) – the maximum length of a vessel’s hull measured parallel to the waterline.
- Gross tonnage (GT) – the volumetric area of the hull up to the freeboard deck, plus shelter structures and the wheelhouse.
These measures can provide an indication of potential on-board facilities, such as processing activities. However, they cannot be used to accurately determine the nature of on-board processing, the extent of processing at sea or weight of landings.

Fishing vessels, of varying sizes, have differing levels of sophistication and on-board facilities. For ease, these are grouped into three size ranges:

- **Large vessels** (>35 m LOA) are likely to have some on-board processing facilities capable of producing a range of products, such as fillets, headed and gutted fish, or cooked and peeled shellfish. They are typically highly mechanised, with on-board freezing capacity. Fishing trip lengths would likely extend to weeks.
- **Smaller vessels** (24 m and <35 m LOA) could theoretically cover either type of operation.
- **Fishing vessels** (<24 m and <35 m LOA) could theoretically cover either type of operation.

Fishing vessels are registered to a state/country and are required by law to carry the flag of that state and also follow the rules and regulations enforced by the same.

This is commonly referred to as the ‘flag state’. For a country to be included in the list of flag states, it must adhere to all the norms and regulations established by the International Maritime Organisation (IMO). The practice of registering a vessel to a nation different than that of the vessel owner is known as the flag of convenience (FOC).

Data relating to the registration of fishing vessels will refer to the flag state. Although fishing vessels can typically land their catch in any port in any country (subject to official approval), fish landings data will refer back to the flag state but include landings in domestic ports and abroad (OECD, 2022).

### 1.4. Fishing gear types

There are a myriad of types of fishing gear, internationally classified into main groups and sub-groups (see Appendix). The table below includes a summary of the main categories and a brief description.

Within each main category of fishing gear there are numerous sub-categories, providing an indication of the variation in fishing gears that may be used globally.

Not all fishing gears are used in every major region. Legislative requirements for managing fisheries, fish stocks and fishing grounds will govern the use and type of fishing gear. The type of gear will be tailored according to the target species, fishing ground, fishing depth etc. Other variations will include, for example, modifications with selectivity devices.

The fishing vessel will be designed/developed to suit the method of fishing. For example, higher-powered vessels are needed for towed gears. Fishing vessels can also be licensed to use more than one type of fishing gear to enable them to target different species at different times, for example in different fishing seasons.

<table>
<thead>
<tr>
<th>Main category of fishing gear</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surrounding nets</td>
<td>A surrounding net is a long piece of net that is constructed mostly from rectangular sections of netting framed by ropes and catches fish by surrounding a school of fish.</td>
</tr>
<tr>
<td>Seine nets</td>
<td>Seine nets can be cone-shaped nets with long wings and a codend, or a long piece of net without a codend, catching fish by entangling and entrapment.</td>
</tr>
<tr>
<td>Trawl</td>
<td>The trawl is a cone-shaped body of netting, usually with one codend, towed behind one or two boats to catch fish through herding and sieving.</td>
</tr>
<tr>
<td>Dredges</td>
<td>A dredge is a cage-like structure often equipped with a scraper blade or teeth on its lower part, either pulled or towed to dig animals out of substrates and lift them into the cage or bag.</td>
</tr>
<tr>
<td>Lift nets</td>
<td>A lift net is a piece of netting mounted onto a frame that is lowered into the water to allow fish to enter the area above the net and is then lifted or handed upward to collect the fish accumulated there.</td>
</tr>
<tr>
<td>Fishing gear</td>
<td>Fishing gear is a net or a basket-like structure which is cast, pushed down, or allowed to fall from above to catch fish underneath it.</td>
</tr>
<tr>
<td>Gillnets and entangling nets</td>
<td>Gillnets and entangling nets are long rectangular walls of netting that catch fish by gilling, wedging, snagging, entangling or entrapment in pockets.</td>
</tr>
<tr>
<td>Traps</td>
<td>Traps are stationary structures of many shapes and sizes into which fish are guided, or pushed by the current, or drawn into the gear by bait or other attractants.</td>
</tr>
<tr>
<td>Hooks and lines</td>
<td>Hook-and-line gears are those that use hooks (including Jigs and lines) to catch fish.</td>
</tr>
<tr>
<td>Miscellaneous gear</td>
<td>Miscellaneous gears include all other gears not included in other categories. There are a variety of other gears in world fisheries, especially in small-scale and artisanal fisheries, include harpoons, rakes etc.</td>
</tr>
</tbody>
</table>
In order to identify the extent of processing seafood at sea, the types of vessels used and which flag states they are registered to, two main research areas were undertaken: desk-based research and questionnaires/ interviews with key stakeholders.

The project commenced in late January 2022, with a completion date of 10 March 2022.

2. Methodology

2.1. Desk-based research

The main elements of the desk-based research focused on:
- Fishery and vessel data i.e. global and regional catch data, processing at sea, fishing vessels
- Fish product/by-product yields
- Nutritional composition of by-products.

2.1.1 Fishery and vessel data

Between 24 January and 4 February 2022, online searches were undertaken using Google. Search terms included combinations of the following:
- Demersal/pelagic/whitefish/squid
- Global production/capture statistics
- World capture landings
- Processing at sea/fishing/fishing vessels.

All fishery data used is publicly available, with fish landings data derived from global sources (Food and Agriculture Organization of the United Nations, 2022). A copy of the full dataset was obtained from the individual tables and reconstructed into a relational database. This facilitated analysis of the catch data with other factors such as by-product yields.

All catch data is presented in live weight/live weight equivalent, unless otherwise stated.

Global records/lists of fishing vessels were identified through the online searches. These were supplemented by additional online searches for fishing vessels by size, type, flag state, and any information on processing at sea.

2.1.2 By-product yields

Between 24 January and 4 February 2022, online searches were undertaken using Google and Google Scholar. Search terms included combinations of the following terms:
- Fish/shellfish (groups of species-specific names including cod, pollack, tuna and squid were also used)
- Edible portion/yield/processing yield
- By-product portion/yield.

All the data used is publicly available.

2.1.3 Nutritional data

Between 24 January and 9 February 2022, online searches were undertaken using Google and Google Scholar. Search terms included combinations of the following terms:
- Fish/shellfish (groups of species-specific names including cod, pollack, tuna and squid were also used)
- By-products/waste
- Nutritional value/proximate analysis/composition/benefits/minerals.

The authors had access to relevant data from previous research projects that had been published.

All the data is from publicly available sources.

2.2. Questionnaires and interviews

To elicit commercial knowledge from different regions, two questionnaires were devised.

The first questionnaire was detailed and included a series of questions to understand current practices (see Appendix). This initial questionnaire was distributed to a series of industry stakeholders between 1 and 8 February 2022. Closing dates were up to 15 February (see Appendix).

A shorter and simpler questionnaire was produced online (Google Forms) and issued on LinkedIn with open access on 8 February 2022. The closing date was 18 February 2022 (see Appendix).

A limited number of interviews were conducted only for the purposes of developing case studies (Table 3). With the limited responses available, the results are used for context in various sections of the report. Responses to the questionnaires are collated and summarised in the Appendix.

### Table 3: Summary of responses to questionnaires and interviews

<table>
<thead>
<tr>
<th>Distribution method</th>
<th>Responses received</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire 1 - detailed</td>
<td>Direct to 30 stakeholders</td>
</tr>
<tr>
<td>Questionnaire 2 - simple</td>
<td>Via LinkedIn (unknown number) and direct (10)</td>
</tr>
<tr>
<td>Interviews</td>
<td>Online discussions</td>
</tr>
</tbody>
</table>
3. Global catch and fishing fleets

Before considering processing at sea it is essential to understand the global catch – i.e. capture of fish and shellfish – and the global fishing fleet.

3.1. Global catch

The Food and Agriculture Organization estimates of wild-caught species, based on 2019 catch data (FAO, 2020), were 108 million tonnes (live weight), comprising:
- 40 million tonnes ‘demersal fish’ species
- 30 million tonnes ‘pelagic’ fish species
- 38 million tonnes ‘shellfish’ fish species.

For the purposes of this report, the primary species groups of relevance are demersal species, pelagic species (tunas, bonitos and billfish), and shellfish (squid). This is based on the assumption that the majority of other pelagic and shellfish species are less likely to be processed at sea. While there are exceptions to this (e.g. pelagic freezer trawlers), with limited evidence available it is a reasonable assumption.

Table 4 describes catch production of the main species groups of primary relevance to this report.

Key findings
- The combined weight of the groupings ‘Cods, hakes, haddocks’ and ‘Flounders, halibuts, soles’ comprises 45% of the catch production, for the species groups of primary relevance.
- After ‘Marine fish – not identified’, the greatest weight captured is represented by the group ‘Cods, hakes, haddocks’ (21.7% of catch production, for the species groups of primary relevance).

3.2 Regional catch data (continents)

Global catch is presented on a regional basis to show the geographical variation in tonnage (tonnes) captured. The table below (Table 5) describes global catch in terms of ISSCAAP categories/species according to the FAO continental designations.

Table 6: Total weight of key species caught by country (flag state)

<table>
<thead>
<tr>
<th>Species (in order of catch weight of)</th>
<th>Total catch (millions of tonnes)</th>
<th>Main countries / flag state capturing species (in order of weight of catch by country)</th>
</tr>
</thead>
</table>

Key findings
- The majority of the ‘Cods, hakes, haddocks’ and the ‘Flounders, halibuts, soles’ are captured within Europe and the Americas.
- ‘Tunas, bonitos, billfishes’ are caught mainly in the Americas, Asia and Oceania.
- Asia accounts for the majority of fish captured within the categories ‘Miscellaneous demersal’ and ‘Marine fish not identified’.

3.3 Catch data for key species, by main countries (flag state)

Within the ISSCAAP species groups, the majority of the global catch is dominated by a few key species and is targeted by a relatively small number of countries.

Table 6 shows the total tonnage (tonnes) captured for the top 15 species, together with the main countries that target each species.
3. Global catch and fishing fleets

**3.4.1 Global levels of loss and wastage**

A large proportion of fisheries and aquaculture production is either lost or wasted: about 35% of the global harvest (FAO, 2020). The main causes for these losses are inefficiencies in value chains and inadequate infrastructure, services and practices (Table 7). The scope of processing, general assumptions can be used (Blackhurst pers. comm.):

- Vessels <10 m LOA are less likely to undertake significant processing at sea beyond basic catch sorting, washing and possibly some gutting (finfish).
- Vessels 10 m to 24 m LOA may undertake some processing, but likely just catch sorting, washing and gutting (finfish).
- Vessels >24 m LOA are more likely to be processing at sea (to varying degrees).

FAO provides general data on fishing vessels >24 m LOA (Figure 1). It is evident that these are a small proportion of the global fishing fleet.

Using these figures and the estimates of the global fleet, it is possible to calculate the potential number of fishing vessels >24 m LOA in each continent (Table 8) (see Appendix for further information). This is the most basic way to provide an estimate of the fishing vessels engaged in processing-at-sea operations. The list of continents is useful as a broader overview due to the lack of data available for all flag states.

**3.5 Global fishing fleet and fishing vessels**

In 2018, the total global number of fishing vessels was estimated to be 4.56 million (FAO, 2020).

In the same year:

- The number of motorised fishing vessels totalled 2.67 million.
- Over 80% of motorised fishing vessels in each major region were <10 m LOA. In Africa, Asia and Oceania this figure was closer to 90%:
- There were almost 68,000 fishing vessels with an LOA of at least 24 m. This was approximately 3% of all motorised fishing vessels.

**3.5.1 Global fishing fleet and vessel size profiles**

Data on the global number of fishing vessels and the extent of on-board processing was not identified during the research phase of the project. As such, assumptions have been made and estimates have been produced. Regarding the size of vessels and extent of on-board processing, general assumptions can be used (Blackhurst pers. comm.):

- Vessels <10 m LOA are less likely to undertake significant processing at sea beyond basic catch sorting, washing and possibly some gutting (finfish).
- Vessels 10 m to 24 m LOA may undertake some processing, but likely just catch sorting, washing and gutting (finfish).
- Vessels >24 m LOA are more likely to be processing at sea (to varying degrees).

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3. Global catch and fishing fleets

Linking different data on fishing vessels >24 m LOA can be challenging; however, the information in Table 8 was also cross-referenced with data on the use of automatic identification systems (AIS) (Taconet, 2019). This data includes a list of the top 20 countries where fishing vessels >24 m LOA use AIS (see list below). First on the list, with two-thirds of the world’s fishing vessels larger than 24 m, is China.

1. China
2. Japan
3. Indonesia
4. Papua New Guinea
5. Republic of Korea
6. Argentina
7. USA
8. Italy
9. Russia
10. Peru
11. Malaysia
12. Venezuela
13. Taiwan Province of China
14. Norway
15. Myanmar
16. Morocco
17. Thailand
18. Mexico
19. Spain
20. Tunisia

Cross-referencing these figures with an incomplete dataset on fishing vessels grouped by LOA (OECD, 2022) provides an estimate of the number of vessels overall in each size category (Table 9). Unfortunately, this dataset only includes 32 countries/nations as members of the OECD, meaning the figures are underestimated. However, this data is further broken down by smaller size ranges and by country (see Appendix), and is useful as an indication for specific countries.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Unidentified LOA</th>
<th>&lt;25m LOA</th>
<th>&gt;25m LOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>All regions</td>
<td>1,633,881</td>
<td>248,354</td>
<td>5,848</td>
</tr>
</tbody>
</table>

3.5.2 Types of fishing gear used by vessels undertaking processing at sea

The profile of commercial fishing gear used by vessels >24 m LOA varies greatly. Based on the information available, a summary of the main types of fishing gear used for the species of main commercial interest is provided (Table 10).

**Key findings**

- Vessels >24 m LOA are most likely to be engaged in some processing-at-sea operations.
- There are almost 68,000 vessels globally >24 m LOA. The majority of these (nearly 80%) are registered in flag states in Asia.
- The lack of data means it is challenging to provide exact figures for these 68,000 vessels including types of on-board processing facilities, extent of processing, exact weight of capture etc.
- Based on the key species, various types of fishing gear will be used by vessels undertaking processing at sea. Most typical gear types would include trawls, longline, purse seine, and jiggers (squid).

**KNOWLEDGE GAPS**

- The number of vessels and extent of processing facilities on board.
- The extent of processing undertaken by fishing vessels, based on vessel size range.

**Table 9: Vessel size profiles by country in 2018 (not all countries are represented in the dataset)**

<table>
<thead>
<tr>
<th>Countries</th>
<th>Unidentified LOA</th>
<th>&lt;25m LOA</th>
<th>&gt;25m LOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>All regions</td>
<td>1,633,881</td>
<td>248,354</td>
<td>5,848</td>
</tr>
</tbody>
</table>

**Table 10: The various gear types most likely to be used by vessels >24m LOA used to target the main species /groups of interest to this report**

<table>
<thead>
<tr>
<th>Species</th>
<th>Demersal/ beam trawl</th>
<th>Otter trawl</th>
<th>Gillnet and pound nets</th>
<th>Hook and line handline</th>
<th>Longline</th>
<th>Pair trawling</th>
<th>Pole and line</th>
<th>Hook and handline</th>
<th>Purse seine</th>
<th>Trolling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cod</td>
<td>x</td>
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<tr>
<td>Pollock</td>
<td>x</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haddock</td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>Hakes</td>
<td>x</td>
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<td></td>
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<tr>
<td>Flounder (plaice etc)</td>
<td>x</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Halibut</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sables</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuna</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Processing at sea: by-product yields and current practice

Published data on the global production of by-products produced at sea was not identified. Therefore, estimates based on global catch and by-product yields are provided. It is impossible to determine with any accuracy the extent of processing at sea, and thus the by-products generated. As such, all figures should be classed as indicative only.

Current practices show a significant variation between regions, extent of processing of the same species and different species etc. The majority of published catch data is converted to ‘live weight equivalent’ in order to standardise reporting volumes. It was outside the scope of this report to refer to data sources in every country.

Through industry knowledge and experience, a number of broad presumptions have been made before providing estimates of by-products (Table 1). However, for almost every presumption there are exceptions.

4.1 Species processed at sea and extent of processing

Not all species are processed at sea, and the extent of processing varies significantly. Table 12 highlights the variability of processing activities carried out at sea for examples of commercially important fish and shellfish.

Table 11: Presumptions and exceptions regarding at sea processing

<table>
<thead>
<tr>
<th>Presumption</th>
<th>Exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Majority of demersal species are processed at sea. Minimum is gutting but can vary to fully processed i.e. Bleated and frozen.</td>
<td>- Small demersal species can be landed whole. - Other components may be retained as products for human consumption, for example heads, cheeks.</td>
</tr>
<tr>
<td>When demersal fish are gutted at sea the viscera are typically thrown overboard.</td>
<td>- This does not apply to larger vessels, who are processing at sea, if they have on-board by-product processing and storage. - Livers may be retained by smaller vessels so long as the livers are a suitable size.</td>
</tr>
<tr>
<td>Majority of pelagic fish are landed whole, processed on-shore.</td>
<td>- Pelagic fleets vary and there are pelagic freezer fleets, who are processing and freezing at sea, however they represent a small proportion of global pelagic vessels. - By-products may be retained and used in feed / food uses.</td>
</tr>
<tr>
<td>Tuna is bled at sea, may be gilled and gutted</td>
<td>- Tuna processing at sea is highly variable and includes a significant amount of tuna retained onboard. This is from frozen whole but the blood leaches into the brine solution during freezing. The extent of processing varies depending on size / species of tuna, market requirements.</td>
</tr>
<tr>
<td>Crustacea (prawns, shrimp, crabs, nephrops) are landed whole / intact</td>
<td>- Cold water prawns can be processed at sea (peeled), or just frozen and landed whole, or - Crabs can be landed whole / live or claws only. - Nephrops can be landed whole/live, whole/dead or as tails (head / claws removed at sea)</td>
</tr>
<tr>
<td>Molluscs / bivalve molluscs are not processed at sea</td>
<td>- None identified.</td>
</tr>
</tbody>
</table>

Table 12: Extent of processing at sea for a number of main types of fish and shellfish

<table>
<thead>
<tr>
<th>Evisceration (gutting)</th>
<th>De-heading</th>
<th>Skinning</th>
<th>Reminding (cutting fins and belly flaps)</th>
<th>Filleting (or portion creation)</th>
<th>Gill Removal</th>
<th>Bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demersal</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cod Hake</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haddock</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alaskan Pollack</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atlantic cod</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelagic</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelagic fish</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mackerel, herring, blue whiting</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skippack Tuna</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellowfin Tuna</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shellfish</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squid</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crabs</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prawns</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 13: Percentage yields of by-product categories for main ‘types’ of fish, based on live weight.

<table>
<thead>
<tr>
<th>Fish Type</th>
<th>By-product categories and % yields</th>
<th>By-products after filleting (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guts (%)</td>
<td>Head and Guts (%)</td>
<td>Pelagic fish (demersal)</td>
</tr>
<tr>
<td>Roundfish (demersal)</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>Flatfish (demersal)</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Squid</td>
<td>26</td>
<td>26</td>
</tr>
</tbody>
</table>

Key findings

- Demersal species are typically gutted as a minimum, although there are exceptions.
- Pelagic fish are typically landed whole, although there are exceptions.
- Tuna can be processed to varying degrees or landed whole.
- Of the shellfish, squid are most likely to be processed.

Further detail on the variation in percentage yields obtained for different fish species/fish ‘types’ is presented in the Appendix.
4. Processing at sea: by-product yields and current practice

4.3 Current practice with processing and retention of by-products at sea

This section includes an overview of the responses from the questionnaires and surveys (Tables 14 to 18). They provide a simple overview of the level of processing carried out on some of the main species captured across different geographical locations. The limited number of questionnaire responses (8) means this is only a broad indication for a limited number of species.

Table 14: Commercial species and current practice for on-board by-products (based on 8 questionnaire responses)

<table>
<thead>
<tr>
<th>Species</th>
<th>At-sea processing</th>
<th>% Wt. of catch processed at sea</th>
<th>% By-product retained on board</th>
<th>By-products retained on board</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>Alaska pollock</td>
<td>Gutting; Heading; Filleting</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Europe (freezing at sea fleet only)</td>
<td>Cod; Haddock</td>
<td>Washing</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>South America, Peru</td>
<td>Mahi Mahi (Coryphaena hippurus); Humboldt or giant squid (Dosidicus gigas)</td>
<td>Gutting; Heading</td>
<td>100%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Findings
- By-products can be retained or discarded overboard if the on-board storage is full.
- The by-products generated by the artisanal fleet for mahi mahi, Humboldt squid and sharks are often fed on by seabirds after being discarded.

Table 15: Commercial species and current practice for on-board by-products (tuna)

<table>
<thead>
<tr>
<th>Species</th>
<th>At-sea processing</th>
<th>% Wt. of catch processed at sea</th>
<th>% By-product retained on board</th>
<th>By-products retained on board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe - Netherlands</td>
<td>Skipjack tuna</td>
<td>No</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Yellowfin tuna</td>
<td>Washing</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Bigeye tuna</td>
<td>Washing</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Findings
- Catch is frozen whole, round on-board.
- All tuna is fished by industrial, large-scale purse-seine vessels.
- Vessels brine-freeze the catch within 15 minutes of hauling the nets on board.

Table 16: Commercial species and current practice for on-board by-products (toothfish)

<table>
<thead>
<tr>
<th>Species</th>
<th>At-sea processing</th>
<th>% Wt. of catch processed at sea</th>
<th>% By-product retained on board</th>
<th>By-products retained on board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Dissostichus eleginoides; Dissostichus mawsoni</td>
<td>Gutting; Heading; Gutting</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Findings
- Some by-products are retained on board and supplied for human consumption.
- There is limited ability to process by-products due to lack of space, lack of on-board treatment/storage, or a lack of time for the crew to process them.
- There is limited/no demand for by-products, so they are not cost-effective to retain.
- Catching season is limited to 10 days – so fishers focus 100% on retaining the most valuable product.

Table 17: Commercial species and current practice for on-board by-products (various)

<table>
<thead>
<tr>
<th>Species</th>
<th>At-sea processing</th>
<th>% Wt. of catch processed at sea</th>
<th>% By-product retained on board</th>
<th>By-products retained on board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Toothfish; babyfish; Orange Roughy; Red snapper; Gold band snapper; Blue-eye Trevally; Seabase tail snapper</td>
<td>Gutting; Heading; Gutting; Heading; Gutting; Production of skin-on fillets</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Findings
- Some by-products are retained for human consumption.
- Generally, guts are removed from fish for food safety and storage reasons.
- With some wholefish (e.g. icefish), guts are retained as the fish are cooked whole.
- Lack of space on board constrains ability to retain all by-products.

Table 18: Commercial species and current practice for on-board by-products (various, tuna)

<table>
<thead>
<tr>
<th>Species</th>
<th>At-sea processing</th>
<th>% Wt. of catch processed at sea</th>
<th>% By-product retained on board</th>
<th>By-products retained on board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Nations - Palau, FSM, Nauru, Kiribati, Tuvaku; Nauru; Solomon Islands, PNG and Tokelau</td>
<td>South Subarctic pollock; Thunnus obesus; Thunnus obesus</td>
<td>Freezing only</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Findings
- The purse seine fishery brine-freezes the whole catch in typically 65-tonne capacity wets.
- The bloody brine is pumped out when pulling temperature down to -18ºC and is discharged either at sea or in port.

Key findings
- Demersal species are typically gutted, and often de-headed.
- Tunas can be processed or landed whole.
- Targeted by-products (e.g. cheeks, trimmings) are for human consumption. Combined by-products are for fishmeal production.
- Lack of space and capacity limits the ability to process and retain by-products.
- There is no market demand/value for the majority of by-product formats.
- Operators prioritise the valuable fishery products.

Knowledge Gaps
- Information on processing activities at sea according to location (countries)
- Information on processed volumes/format produced on a regional basis
- Information on processed volumes/format retained for specified use (human/non-human)
- Information on processed volumes/format discarded from vessels
- Information on processing volumes/format by main commercial species
- Information on processed volumes/format discarded from vessels
5. Nutritional composition of by-products

The priority for deriving nutritional value has traditionally focused on the edible portions of seafood products, i.e., the typical formats such as fillets, meats etc.

For fish and shellfish products, in Europe for example, there are national reference databases providing standard nutritional data for a wide variety of foods, prepared in a wide variety of formats. One such example is McCance and Widdowson’s (Composition of foods integrated dataset (CoFID), 2015, updated 2021) in the UK. This data does not include by-products and there is seemingly no equivalent for by-products.

While there is data available on the composition of by-products it is primarily focused on specific commercially important species, notably in the northern hemisphere, or on emerging species of significant value. Species produced in aquaculture have been a recent area of focused research.

There is much data available for the converted products after further processing, e.g., dried powders/flours, ensiled material, fermented sauces, feed ingredients, meals, oils etc.

From the data available it is evident that by-products have been studied in varying degrees. This ranges from detailed analysis of single by-products (e.g., eyes, bones, skin) through to combinations of by-products (e.g., head, viscera) to identify valuable components (Table 19).

For human dietary purposes, the main area of interest is fundamental nutritional characteristics (e.g., protein, minerals, and oils/lipids). By compiling various publicly available sources, it is possible to provide broad nutritional information for by-products.

The data available shows fish by-products provide vital vitamins, minerals and proteins which are essential in the diet.

This section of the report provides summary data for each area of nutrition. See Appendix for detailed data.

### 5.1 Proximate composition (moisture, protein, fat)

The composition of seafood varies according to the type of species, sex, nutritional status, time of year (e.g. spawning) and overall health. This can result in significant variations in levels of moisture, protein and fat.

This variation is also seen in the proximate composition data for by-products (Tables 20 and 21).

#### Table 19: Summary of valuable components of marine by-products (Shahidi, 2006) (Francisco J Martí-Quijal, 2019)

<table>
<thead>
<tr>
<th>Lipids</th>
<th>Proteins</th>
<th>Other components</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Oils</td>
<td>• Enzymes</td>
<td>• Nutric acid</td>
</tr>
<tr>
<td>• Omega-3 (EPA, DHA, fatty acids)</td>
<td>• Hydrolysis (enzymes, chemically or enzymatically broken down to peptides)</td>
<td>• Calcium</td>
</tr>
<tr>
<td>• Phospholipids</td>
<td>• Thermostable dispersions</td>
<td>• Phosphorous</td>
</tr>
<tr>
<td>• Squalene</td>
<td>• Peptides, amino acids</td>
<td>• Basidiole compounds</td>
</tr>
<tr>
<td>• Vitamins</td>
<td>• Gelatine, collagen</td>
<td>• Colours</td>
</tr>
<tr>
<td>• Cholesterol</td>
<td>• Protamine</td>
<td>• Chitin / chitosan / glucosamine / chondroitin</td>
</tr>
</tbody>
</table>

#### Table 20: Proximate composition value ranges for different species (various sources, see Appendix)

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Protein</th>
<th>Fat</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>% wet weight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cod</td>
<td>73-85</td>
<td>12-24</td>
<td>15-23</td>
</tr>
<tr>
<td>Pollock</td>
<td>81.3-81</td>
<td>16-19</td>
<td>14-19</td>
</tr>
<tr>
<td>Halibut (heads only)</td>
<td>86.5</td>
<td>18.1</td>
<td>18.2</td>
</tr>
<tr>
<td>Salmon (Alaskan)</td>
<td>87-81</td>
<td>13-16</td>
<td>2-16</td>
</tr>
<tr>
<td>Haddock</td>
<td>7-18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ling</td>
<td>8-20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crab (various species)</td>
<td>75-77</td>
<td>8-14</td>
<td>5-2</td>
</tr>
</tbody>
</table>

#### Table 21: Proximate composition of ‘fish by-products’ (Ghaly, 2013)

<table>
<thead>
<tr>
<th>Crude protein</th>
<th>Fat</th>
<th>Ash</th>
<th>Crude fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>% dry matter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-specified ‘fish by-products’</td>
<td>12.9 ± 0.16</td>
<td>1.4 ± 0.08</td>
<td>2.79 ± 0.12</td>
</tr>
</tbody>
</table>

If by-products were to be separated by the component parts, it is evident that each part would yield a different composition, as can be seen in data for Alaska pollock (Table 22).

#### Table 22: Proximate composition of different components of Alaska pollock (Alaska Sea Grant College Program, 2003)

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Protein</th>
<th>Fat</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole fish</td>
<td>86.7</td>
<td>16.6</td>
<td>30.8</td>
</tr>
<tr>
<td>Fillets</td>
<td>84.9</td>
<td>1.9</td>
<td>5.2</td>
</tr>
<tr>
<td>Head</td>
<td>87.4</td>
<td>5.2</td>
<td>59.4</td>
</tr>
<tr>
<td>Frame</td>
<td>78.6</td>
<td>3.9</td>
<td>44.5</td>
</tr>
<tr>
<td>Viscera</td>
<td>81.2</td>
<td>4.7</td>
<td>16</td>
</tr>
<tr>
<td>Skin</td>
<td>87.5</td>
<td>1.7</td>
<td>8.8</td>
</tr>
</tbody>
</table>

**Key findings**

- From the data it is evident that fish products can be a valuable source of proteins and fats. They contain high-quality proteins and lipids with long-chain omega-3 fatty acids.
- Detailed information on the fatty acids content of by-products is more limited but it is evident that by-products are a source of saturated fatty acids (SFA), polyunsaturated fatty acids (PUFAs), and monounsaturated fatty acids (MUFAs). Omega-3 and omega-6 fatty acids are PUFAs, and omega-9 fatty acids are usually MUFAs.
- The composition of by-products varies between species and component parts. Understanding the composition of different by-products is useful in order to utilise by-products in specific products or uses.
- The nutritional value of by-products will fluctuate. However, it will be particularly influenced by the quality of the raw material. By-products are typically prone to more rapid spoilage and would need to be preserved to avoid loss of nutritional value.
5. Nutritional composition of by-products

5.2 Micronutrients and amino acids

Fish by-products provide levels of micronutrients that are essential in the diet. These have been quantified in varying levels, depending on the species and by-product components (see Appendix). Micronutrients identified in by-products include:

- Vitamins A, D, B, particularly B-12
- Minerals: calcium, copper, iodine, iron, magnesium, manganese, potassium, phosphorous, selenium, sodium, zinc.

Amino acids have also been found in by-products. The human body needs different amino acids to maintain health and normal functioning. The data shows amino acids are found in varying levels, depending on the species and by-product components.

The amino acids identified in by-products include alanine, arginine, asparatic acid, cysteine, glutamic acid, glycine, hydroxyproline, isoleucine, leucine, lysine, methionine, phenylamine, proline, serine, valine, histadine, theonine, and tyrosine.

5.3 Contaminants

Numerous studies have been undertaken on the benefits versus risks of eating seafood, including by the WHO and FAO (World Health Organization & Food and Agriculture Organization of the United Nations, 2011). Seafood is an important part of the global diet but there can be issues in some products, derived from specific species caught in specific areas. This may be particularly true for some by-products, notably viscera and livers, where contaminants are more likely to accumulate. Other by-products, such as heads and cheeks, are less likely to accumulate contaminants.

The benefits of seafood consumption far outweigh any risks (albeit vulnerable groups need to follow specific advice tailored to their circumstances). This is based on known data relating to the typical edible portions like fillets, meats, lobs etc. It is not evident if this conclusion applies to the range of by-products that may be consumed.

By-products for direct human consumption (e.g. cheeks) are subject to exactly the same safety requirements that apply to any seafood products for the human food chain. When by-products are further processed and used in the production of new products (e.g. oils, protein powders, meats, sauces etc) they undergo additional testing and processing. Oils, for example, are refined to ensure their safety.

From the limited data identified, by-products may be a source of contaminants. In 2011, the WHO and FAO recommended that countries/regions:

- “Develop, maintain and improve existing databases on specific nutrients and contaminants in fish consumed in their region”
- “Develop and evaluate risk management and communication strategies that both minimize risks and maximize benefits from eating fish”

KNOWLEDGE GAPS

- The data available on by-products is variable in content, scope and analytical method. This makes it challenging to draw comparisons and conclusions.
- Data is not available for all the commercially caught species where by-products are produced.
- Data is not available to better understand if specific by-products are better targeted or used for specific uses.
- The loss of nutritional value influenced by spoilage of by-products.
- The levels of any contaminants in by-products, particularly internal organs.
- The benefits and risks of eating different by-products.
6. Estimates of by-products at sea and their protein value

Information on by-product yields (Section 4) is used to produce estimates of by-product quantities for each ISSCAAP grouping/species. Detailed information on the exact amount or proportion of catch that is processed at sea is unavailable. It is evident from the questionnaires and anecdotal information that the proportion of the catch that is processed at sea is highly variable. Similarly, the extent of processing can vary; for example, from partial processing (gutting) through to full filleting.

To provide an estimate of by-products produced at sea, two different ranges are used to reflect the variations in the quantity of catch that may be processed and the extent of processing that may be undertaken:

1. Three proportions (25%, 50% and 100%) are applied to the total catch quantity. These provide a basis for quantifying the amount of the catch that may be processed at sea.

2. Three levels of processing at sea are also included (gutted, headed and gutted, fully processed). These reflect the main variations in the extent of by-products produced, based on the weight of the whole fish (i.e. live weight). For example, for cods, hakes and haddock:
   - Gutting generates 16% by-products.
   - Heading and gutting generates 37% by-products.
   - Fully filleting generates 64% by-products.

The combination of these ranges has been applied to the total weight of the global catch, for each main species groups.

6.1 Estimates of by-products produced at sea, by species groups

When the two ranges are applied to the total catch of each main group or species (based on ISSCAAP grouping/species), it is possible to provide broad estimates (Tables 23 to 30).

The catch data is presented as tonnes of live weight. By-product data is calculated by product weight.

Table 23: Estimated tonnes of by-products: Cod hakes and haddocks

<table>
<thead>
<tr>
<th>By-product tonnes: Guts (26%)</th>
<th>By-product tonnes: Head &amp; Guts (37%)</th>
<th>By-product tonnes: Full processing into skinless fillets (41%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.37</td>
<td>0.74</td>
<td>2.98</td>
</tr>
<tr>
<td>0.15</td>
<td>0.30</td>
<td>1.10</td>
</tr>
<tr>
<td>0.15</td>
<td>0.30</td>
<td>1.10</td>
</tr>
</tbody>
</table>

Table 24: Estimated tonnes of by-products: Flounder, halibut and soles

<table>
<thead>
<tr>
<th>By-product tonnes: Guts (9%)</th>
<th>By-product tonnes: Head &amp; Guts (31%)</th>
<th>By-product tonnes: Full processing into skinless fillets (60%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02</td>
<td>0.05</td>
<td>0.56</td>
</tr>
<tr>
<td>0.08</td>
<td>0.15</td>
<td>0.80</td>
</tr>
<tr>
<td>0.15</td>
<td>0.30</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 25: Estimated tonnes of by-products: Tuna, bonitos, billfish*

<table>
<thead>
<tr>
<th>By-product tonnes: Guts (5%)</th>
<th>By-product tonnes: Head &amp; Guts (50%)</th>
<th>By-product tonnes: Full processing into skinless fillets (50%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18</td>
<td>0.35</td>
<td>0.65</td>
</tr>
<tr>
<td>0.53</td>
<td>1.05</td>
<td>2.11</td>
</tr>
<tr>
<td>0.53</td>
<td>1.05</td>
<td>2.11</td>
</tr>
</tbody>
</table>

Table 26: Estimated tonnes of by-products: Miscellaneous demersal fish

<table>
<thead>
<tr>
<th>By-product tonnes: Guts (6%)*</th>
<th>By-product tonnes: Head &amp; Guts (17%)*</th>
<th>By-product tonnes: Full processing into skinless fillets (64%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.45</td>
<td>0.90</td>
<td>3.92</td>
</tr>
<tr>
<td>0.97</td>
<td>1.94</td>
<td>7.42</td>
</tr>
<tr>
<td>0.97</td>
<td>1.94</td>
<td>7.42</td>
</tr>
</tbody>
</table>

Table 27: Estimated tonnes of by-products: Marine fish - not identified

<table>
<thead>
<tr>
<th>By-product tonnes: Guts (45%)*</th>
<th>By-product tonnes: Head &amp; Guts (17%)*</th>
<th>By-product tonnes: Full processing into skinless fillets (68%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.04</td>
<td>2.10</td>
<td>6.72</td>
</tr>
<tr>
<td>2.03</td>
<td>4.20</td>
<td>12.80</td>
</tr>
<tr>
<td>2.03</td>
<td>4.20</td>
<td>12.80</td>
</tr>
</tbody>
</table>

Table 28: Estimated tonnes of by-products: ‘Marine coastal fisheries’

<table>
<thead>
<tr>
<th>By-product tonnes: Guts (50%)*</th>
<th>By-product tonnes: Head &amp; Guts (50%)*</th>
<th>By-product tonnes: Full processing into skinless fillets (50%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.68</td>
<td>1.36</td>
<td>5.00</td>
</tr>
<tr>
<td>1.20</td>
<td>2.40</td>
<td>8.00</td>
</tr>
<tr>
<td>1.20</td>
<td>2.40</td>
<td>8.00</td>
</tr>
</tbody>
</table>

Table 29: Estimated tonnes of by-products: ‘Squids’

<table>
<thead>
<tr>
<th>By-product tonnes: Guts (4%)*</th>
<th>By-product tonnes: Head &amp; Guts (7%)*</th>
<th>By-product tonnes: Full processing into skinless fillets (69%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.21</td>
<td>0.42</td>
<td>1.28</td>
</tr>
<tr>
<td>0.21</td>
<td>0.42</td>
<td>1.28</td>
</tr>
</tbody>
</table>

Table 30: Estimated tonnes of by-products: ‘Sharks, rays and Chimera’

<table>
<thead>
<tr>
<th>By-product tonnes: Guts (5%)*</th>
<th>By-product tonnes: Head &amp; Guts (9%)*</th>
<th>By-product tonnes: Full processing into skinless fillets (50%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18</td>
<td>0.35</td>
<td>0.65</td>
</tr>
<tr>
<td>0.53</td>
<td>1.05</td>
<td>2.11</td>
</tr>
<tr>
<td>0.53</td>
<td>1.05</td>
<td>2.11</td>
</tr>
</tbody>
</table>

*The research for this report found conflicting information on the extent of tuna processing at sea. Tunas will also be landed whole, as indicated from the responses to the questionnaires. The figures for tuna by-products at sea are included for all tunas, as it is impossible to separate the data sources.

KNOWLEDGE GAPS

- Complete by-product information on ISSCAAP grouping/categories
- Information on the proportion (%) of each species/ISSCAAP grouping processed at sea
6. Estimates of by-products at sea and their protein value

6.2 Estimated total quantity of by-products from processing at sea

Combining the data from all the species groups provides an estimated range of by-products from processing at sea (Table 31). Because of the assumptions and generalities, these figures should be treated with extreme caution and considered only as a broad indication.

6.3 Potential nutritional value of at-sea by-products

Focusing purely on fish as a protein source, the earlier data showed a range of protein levels from 10% to 20% across different by-product types and species. Applying this range to the estimated quantity of by-products potentially available at sea, it is possible to provide an indication of the quantity of protein available if those by-products could be available for consumption (Table 32).

The data in Table 32 is a calculated estimate, based on limited information and incomplete data. It serves only as an indicator of the potential value of at-sea by-products.

<table>
<thead>
<tr>
<th>By-product</th>
<th>25%</th>
<th>50%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>If gutted at sea*</td>
<td>1.41</td>
<td>2.81</td>
<td>5.63</td>
</tr>
<tr>
<td>If headed and gutted at sea*</td>
<td>3.45</td>
<td>6.90</td>
<td>13.79</td>
</tr>
<tr>
<td>If fully processed into skinless fillets / squid fully processed into tubes (30%)</td>
<td>6.31</td>
<td>12.62</td>
<td>25.23</td>
</tr>
</tbody>
</table>

*excludes squid

### Table 31: Estimated quantities of by-products from processing at sea (all species groups)

<table>
<thead>
<tr>
<th>All species groups</th>
<th>Quantity of by-products produced by percentage of catch processed (millions of tonnes)</th>
<th>By-product quantity range (millions of tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Table 32: Estimated total of protein available if at sea by-products derived from the species groups identified in this report, were available for human consumption

<table>
<thead>
<tr>
<th>All species groups</th>
<th>By-product estimated quantity range (millions of tonnes)</th>
<th>Potential protein available (based on wet weight, all by-product types)</th>
<th>Estimated quantity of protein available (millions of tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>3.45</td>
<td>6.90</td>
<td>13.79</td>
</tr>
<tr>
<td></td>
<td>6.31</td>
<td>12.62</td>
<td>25.23</td>
</tr>
</tbody>
</table>
7. Case studies

7.1 Frozen at Sea Fillets Association

Formed in 2000, the Frozen at Sea Fillets Association (FASFA) is the representative trade association of the frozen-at-sea (FAS) industry in the UK.

The FASFA vision is for a thriving, sustainable and profitable fish and chip industry in the UK, through the provision of high-quality FAS cod and haddock fillets sourced from responsibly managed stocks.

FASFA members include international fishing companies, fishing vessels and distributors of FAS filleted cod and haddock. More information about FASFA is on its website - fasfa.co.uk.

Fishing and products

Fishing areas and regions, and target catch
FASFA membership covers companies based in Norway, Iceland, the Faroe Islands, Russia, Greenland and the UK.

The major fishing regions include:
- ARCTIC SEA (Major Fishing Area 18)
- ATLANTIC NORTHEAST (Major Fishing Area 27)

Specific fishing zones include:
- Areas I, IIa, IIb
- IIIa, IIIb
- IVa, IVb

The catch is landed into various ports across the different regions.

The target species for the vessels represented by FASFA are demersal fish (haddock, groundfish, specifically cod (Gadus morhua) and haddock (Melanogrammus aeglefinus)). Depending on quota and market requirements, vessels can switch to fishing for other species including saithe (Pollachius virens) and redfish (Sebastes spp.).

Products

FASFA members produce a significant volume of products in different formats. These formats are driven by market requirements and include frozen fillets.

The annual volume of frozen fillets produced by FASFA members has been static, in the region of 50,000 tonnes per annum; however, this has fluctuated in recent years.

At-sea processing

The FAS vessels are typically >60 m LOA and are designed to utilise every space for the production of their main products for human consumption, i.e. fish fillets.

They are highly mechanised operations, designed for the purposes of processing at sea. The vessels are at sea for long trips, at least 30 days, and can last up to 60 days. Fishing is undertaken in short tows/hauls to manage the throughput for the factory operation below deck. This optimises the quality as the fish are processed and frozen within four hours of capture.

After hauling, the catch is processed into the component parts:
- Products for human consumption are blast-frozen before cold storage.
- By-products removed during mechanised processing are collected and dispatched to a separate area of the processing deck where they are handled/stored.

By-product retention, storage and use

By-products are collected together as it is impossible to separate any of the component parts. This is due to the nature of processing (mechanised) and volume of throughput.

Using a conversion factor of 2.96 (average of the respective conversion factors for calculating live weight equivalent from frozen cod and frozen haddock fillets (EUMOFA), this would equate to 98,000 tonnes of by-products generated from the frozen fillets portion of the catch.

The vessels may also produce headed and gutted (H&G) products. However, no information was available on the quantities of these. The estimate of by-products (previous paragraph) does not include the by-products from processing whole fish into H&G fish.

Space within the vessels is prioritised for the production of fillets and other products for human consumption. The design of the vessel is such that every space is utilised for processing, handling and storage of the catch.

The by-product handling equipment has a specific throughput and will operate at maximum capacity. Such equipment will struggle to cope at times; for example, during peak production.

The by-product handling equipment has a specific throughput and will operate at maximum capacity. Such equipment will struggle to cope at times; for example, during peak production.

By-products, while being an income stream, are secondary to the human consumption products. Space limitations during peak production mean that some vessels can retain all the by-products produced, whereas other vessels may only retain a proportion of the by-products on board. For vessels that have limited storage space, or whose on-board fishmeal equipment cannot handle the volume of by-products, there is a need to dispose of the by-products at sea.

After landing, the processed by-products are supplied for the production of fishmeal and oil. The vessel lands the catch in various ports and will sell the processed/

stabilised by-products to a local fishmeal processor. One example of fishmeal produced at sea by a FASFA member is Norwegian White Fishmeal (ramoren.no).

A number of Icelandic FASFA members have interests in an on-shore collagen production facility, producing collagen and gelatine from fish skins - codlagen.com.

Challenges

The market will always drive the requirements for the landed products. The priority will remain products for human consumption; it would be challenging to retain a greater proportion of by-products due to the limitations in on-board space.

Processing at sea is challenging and subject to many external factors and future influences, including:
- Market demand for product formats may shift between semi and fully processed. This will affect the volume of by-products generated.
- Policy decisions can affect future decisions to invest in processing at sea, for example higher import trade tariffs for higher processed products.
- Fishery management issues such as quotas (availability, costs).
- Climate change (changing migratory patterns for key species).

Future outlook

- Continued focus on vessel efficiency in terms of operations.
- Fuel efficiency is a major future focus.

All information for this case study courtesy of FASFA. Acknowledgements: Julie Waites, Executive Director, Frozen at Sea Fillet Association (FASFA) - fasfa.co.uk.

SPOTLIGHT ON THE KIRKELLA  State-of-the-art freezer vessel registered in the UK

The Hull-based Kirkella was registered in June 2018 and is 81 m long. With 30 crew on board and automated processing, the first fish reach the on-board freezers 40 minutes after being caught.

The vessel’s main fishing areas are Barents Sea, Greenland waters, NAFO (northwest Atlantic), and Norwegian Sea.

Each trawl lasts between 30 minutes and six hours, catching around 12 tonnes of fish per haul. The nets are hauled on board from the stern, then the catch is electronically stunned and conveyed to the onboard factory. The fish are filleted, frozen and packaged in a continuous, highly mechanised process.

The guts, skins and heads are stored separately and processed into fishmeal and used in animal feeds and as a fertiliser. Kirkella can store up to 780 tonnes of fish fillets at -28°C in her onboard cold store. By-product storage is 170 tonnes.

Ref: ukfisheries.net/kirkella-trawler

Acknowledgements: Julie Waites, Executive Director, Frozen at Sea Fillet Association (FASFA) - fasfa.co.uk.
7. Case studies

7.2 At-sea Processors Association

The At-sea Processors Association (APA) is a trade association representing five member companies that participate principally in the Alaska pollock fishery and west coast Pacific whiting fishery. By weight, these groundfish fisheries account for more than one-third of all fish harvested in the US each year.

Further information is available online: www.atsea.org

About the fishery

The mid-water trawl Alaska pollock fishery is the largest fishery in the US and one of the largest fisheries in the world. Approximately 1.88 million tons are harvested annually.

The major fishing region is the US Eastern Bering Sea. The main target species are Alaska pollock (Gadus chalcogrammus) and west coast Pacific whiting (Merluccius productus).

Policy changes and drivers

In 1998, the American Fisheries Act introduced a fundamental change in fisheries management and quotas. Prior to this, the incentive was for vessels to catch as much fish as possible. However, the introduction of new policies and restrictions on fishing resulted in a significant shift towards total catch utilisation. This led to investment in new vessels and upgrades to existing vessels, ensuring the facilities on board could make use of all parts of the fish they caught.

Products

Pollock is typified as a high-volume, low-value fish, with maximum utilisation of the catch.

A variety of seafood products are produced on board including minced fish, fillets (pin bone out and/or deep-skinned), surimi, and fish roe. Fish meal and fish oil are produced from non-flesh parts of the fish.

APA catcher/processor vessels retain and utilise 99.5% of their catch.

At-sea processing

The five members of the APA own and operate 13 US-flag catcher/processor vessels.

The vessels harvest, process, package and freeze the catch within hours of harvest.

Currently, 10 of the vessels have on-board fishmeal and 12 have fish oil producing capabilities. Of the three vessels without fishmeal capacity, one is scheduled for replacement and will include on-board fishmeal and fish oil capability. The remaining two vessels have on-board fish oil production capacity. The vessels range in size from 78 to 116 m LOA. They are highly mechanised operations, designed for the purposes of processing at sea and utilising the totality of the catch. Fishing trips generally last from 8 to 14 days.

The vessels offload their catch and refuel and restock supplies in Dutch Harbor, Alaska. The various products are destined for a number of domestic and global markets.

The fishmeal produced on board is typically exported to China. Fish oil can also be exported, but often in the summer B-season more fish oil is produced than can be stored on board the vessel, therefore it is burned as fuel. It is also used in nutraceutical products.

By-product retention, storage and use

Since the 1998 policy changes, the focus on catch utilisation has created a significant increase in product usage. This is clearly shown in the data and evidence available.

Data from 2016-2018 shows the variety of products produced by volume. Having this data broken down into component parts shows the utilisation of products that, in many other fisheries, would not be retained or landed.

It is evident that the traditional edible portion (fillet) is only a proportion of the number of products produced, with other important products (by weight) being surimi, fish meal and oil, and minced fish.

Over time, the product recovery rate (i.e. utilisation of the fish) has increased significantly (see graphs below).

Between 1999 and 2019, product recovery rates of pollock nearly doubled from 18.14 tonnes of finished product per 90.71 tonnes of round weight pollock catch in 1999 to nearly 36.28 tonnes of finished product per 90.71 tonnes of round weight pollock catch in 2019.

Product mixes have remained relatively stable over the time series, although there has been a slight increase in fish meal and fish oil production as well as some other ancillary products.

Valuing the catch

A recent life cycle analysis for Alaska pollock shows the yields and wholesale prices for various products.

It is evident that the maximum yield is being recovered from the total catch.

There are significant differences in the wholesale values of the component parts of the catch by weight. The highest value was seen for roe, with fillets, surimi and minced fish yielding similar values. Where markets are available for products there is clearly an economic value in all the parts of the catch.

Yield rates and economic values (wholesale price) for Wild Alaska Pollock products (Bering Sea / Aleutian Islands)

Future outlook

Continued focus on total catch utilisation investing in vessels with equipment on board to undertake at-sea processing and retain 100% of the catch.

Acknowledgements

All information for this case study courtesy of and reproduced with permission of the At-sea Processors Association. www.atsea.org

References

• Xinuie Zhang (Quantis), Adam Kolten (Quantis), Melissa Zgola (Quantis), Life cycle assessment of wild Alaska pollock for Genuine Alaska Pollock Producers, June 2021
• North Pacific Fishery Management Council, Pollock Conservation Cooperative and High Seas Catchers’ Cooperative – Joint Annual Report 2019, April 1, 2020
### 7.3 Iceland – 100% Fish Project

(All information and images reproduced courtesy of the website [www.sjavarklasinn.is/en/100-fish](http://www.sjavarklasinn.is/en/100-fish))

Iceland has had a leading reputation for the utilisation of by-products for a number of years, driven by the importance of seafood to the economy.

Ten years ago, the Iceland Ocean Cluster established the 100% Fish Project. The aim of this was to maximise the utilisation of the catch, increase the value of the catch, support new business, increase employment, and avoid wasting a valuable resource.

#### The value of collaboration

The Iceland Ocean Cluster has brought together seafood businesses in a network with the research community and new businesses. This has led to the sharing of challenges and solutions.

#### Research

Working with researchers and technology providers has led to improvements in innovation which have helped maximise the by-products that can be used. The seafood industry has also had to innovate, to improve its handling and processing of by-products.

#### Value creation

Over the past three decades Iceland has invested heavily in this area, and this has led to significant changes in maximising the value of the catch and the utilisation of by-products. The 100% Fish Project states that:

- Icelandic cod producers typically use up to 80% of their raw material.
- Fillet yield has increased by as much as 20% over the past two decades.
- Since the 1990s, the utilisation of fishery by-products has increased 30-fold.
- The export value per cod kilogram has risen by a factor of 4.
- Icelandic producers are getting at least 30% more value from each cod than most developed countries.

Much of this has been driven by innovation and investment, involving multiple businesses and organisations working together. There are multiple companies in Iceland that are now involved in the utilisation of fishery by-products.

#### New products

Beyond the production of seafood, Iceland now produces and trades in:

- Liver
- Cosmetics
- Smoked & dried fish
- Medical products
- Fish leather
- Roe & milt
- Supplements & nutraceuticals
- Omega-3 oil

#### Knowledge transfer

The Icelandic Ocean Cluster is working with other groups, including in the USA and Canada, to transfer knowledge and skills. Its aim is to help support other clusters to maximise the value of the catch in their fisheries.
8. Considerations for on-board retention of by-products

The retention of by-products on board fishing vessels should be considered in a wider context. For example, there may be unintended consequences for the environment, the crew or the vessel; or there may be other factors that have to be considered before by-products could or should be retained, for example market requirements.

The table below provides a summary of some of the considerations that were identified during the production of this report.

<table>
<thead>
<tr>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ecosystem</strong></td>
</tr>
<tr>
<td>Impact on seabirds, predatory species, bottom feeders, general nutrient cycle</td>
</tr>
<tr>
<td><strong>On-vessel</strong></td>
</tr>
<tr>
<td>Fish by-products, especially when containing viscera deteriorate very rapidly. Requires on-board available preservation techniques suited to the types of by-product and market requirements</td>
</tr>
<tr>
<td>Vessel design is optimised for current on-board handling and processing. There may be requirements for vessel modifications</td>
</tr>
<tr>
<td>Increased work for crew to sort and separate the catch into component parts</td>
</tr>
<tr>
<td>Vessel sizes are limited in terms of storage and handling capabilities</td>
</tr>
<tr>
<td>Suitability for small scale fishers (artisanal) would be different compared to larger vessels</td>
</tr>
<tr>
<td>Fishing conditions; warm-water species vs cold-water species, ambient temperatures (effect on spoilage)</td>
</tr>
<tr>
<td><strong>Food safety</strong></td>
</tr>
<tr>
<td>On-board facilities not geared at handling/storing by-products</td>
</tr>
<tr>
<td>Prevention of cross-contamination if viscera (offal) are retained on-board</td>
</tr>
<tr>
<td>Need for rapid handling and effective preservation, some by-products will spoil much more rapidly than products for human consumption</td>
</tr>
<tr>
<td>Heavy metals and contaminants; extent of evidence available on the benefits vs risks of eating portions that may have levels higher than regulatory safety limits</td>
</tr>
<tr>
<td><strong>Economic / market</strong></td>
</tr>
<tr>
<td>Creating a market for by-catch or selective parts of fish if value becomes significant for example brown crab in UK and Ireland, landing claw, market for carapace is volatile and economically challenging at times</td>
</tr>
<tr>
<td>Offsetting the landed value of by-products against the value of catch; with limited space on-board fishing vessels, there could be reduced income for fishers</td>
</tr>
<tr>
<td>Displacement of ingredients currently used for feed purposes, given the forecast demand in marine ingredients for future growth in aquaculture</td>
</tr>
</tbody>
</table>
9. Conclusions and recommendations

Publicly available data is limited in order to quantify the extent of at-sea by-products. However, by using different datasets covering global fish catch, types of by-products and processing yields, catch areas (regions/flag states), and types of fishing vessels, it has been possible to make some very broad statements and estimates. However, these are only indicative. There are major knowledge gaps to consider before estimates can be refined.

From the limited responses received it is evident that the extent of retaining by-products on board is highly variable. Larger vessels (>35 m LOA) which are processing and freezing at sea are most likely to be retaining by-products and using these for human consumption/products, or for feed ingredients. It is apparent that even the larger vessels have limitations when it comes to by-product retention, from on-board storage, crew time to process, product quality and safety, through to perhaps the biggest limitation which is the low market value in most parts of the world. Apportioning by-products the time, valuable storage space and preservation required will always be secondary to the more significant value of the primary edible products.

On-board retention of by-products should not be seen in isolation, as it is evidently not simply a case of encouraging fishers to retain them. Many factors should be considered, not least the usual challenges of balancing supply and demand, but also potential income displacement, vessel design, environmental impacts of removing nutrients from the sea, food safety, on-shore infrastructure for handling, storage and product conversion where necessary.

There are successful examples for maximising the value of the catch, notably in the northern hemisphere. These are a result of long-term investment and collaboration between different parts of the seafood industry, technology providers, business innovators, science and research, and funders. It is a model that is currently aspirational for many other regions, but sharing that knowledge and understanding is instrumental to ensuring the success of any future initiatives to retain and add value to by-products.

**Recommendations:**

- Filling knowledge gaps on species, fishing vessels, current practices.
- Collaboration with leading nations (e.g. Iceland, Norway) to share knowledge and insight.
- Understanding the role of innovation and how this may be best used from the on-board processes and storage through to on-shore infrastructure and product development.
- Market identification and development; seafood is globally traded and that includes by-products. Understanding the demand for by-products.
- Better knowledge of the quality, safety and hygiene requirements for by-products from at-sea processing through to legal requirements e.g. for processing, handling, trade with different nations.
- Understanding the nutritional composition of different by-products for a broader range of species would be useful, to understand the benefits versus risks of directly consuming these products.
References for catch and vessel data

References for by-product yields
- Archer. M et al. (2000). Fish waste production in the UK. https://www.seafish.org/document/?id=b2d0d9d6-27be-4e16-bf36-02b80d5b4a29
- Seafood yields: https://www.chefs-resources.com/aquaculture-seafood-seafood-yields

References for nutritional composition
- Aikaterini Kandylari et al. (2020). Nutrient Composition and Fatty Acid and Protein Profiles of Selected Fish By-Products. Foods 2020; 9, 190: doi/10.3390/foods9020190

References cited
## Appendix I: Classification of fishing gears

<table>
<thead>
<tr>
<th>Gear categories (First tier)</th>
<th>Subcategory (Second tier)</th>
<th>Standard abbreviations</th>
<th>ISSCFG code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SURROUNDING NETS</strong></td>
<td>Purse seines</td>
<td>PS</td>
<td>01</td>
</tr>
<tr>
<td></td>
<td>Surrounding nets without purse lines</td>
<td>LA</td>
<td>01.1</td>
</tr>
<tr>
<td></td>
<td>Surrounding nets (nei)</td>
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<td>Cover pots/Lantern nets</td>
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<td>Falling gear (nei)</td>
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### International Standard Classification of Fishing Gears (ISSCFG), Rev.1 (2016) (He, 2021)

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<th>Gear categories (First tier)</th>
<th>Subcategory (Second tier)</th>
<th>Standard abbreviations</th>
<th>ISSCFG code</th>
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<td>Encircling gillnets</td>
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<td>Fyke nets</td>
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<td>Mechanized lines and pole-and-lines</td>
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<td>Vertical lines</td>
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<td></td>
<td>Hand implements (afterreaching gear, clips, rongs, rakes, spawls)</td>
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<td>Pumps</td>
<td>MPN</td>
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<td>Pushnets</td>
<td>MPN</td>
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</tr>
<tr>
<td></td>
<td>Scoopnets</td>
<td>MSP</td>
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<td></td>
<td>Drive-in nets</td>
<td>MMI</td>
<td>10.7</td>
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<tr>
<td></td>
<td>Diving</td>
<td>MIV</td>
<td>10.8</td>
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<tr>
<td></td>
<td>Gear nei</td>
<td>MIS</td>
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<tr>
<td><strong>GEAR NOT KNOWN</strong></td>
<td>Gear not known</td>
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Nei = not elsewhere identified
Appendices

Appendix II: Questionnaires and responses

Questionnaire 1 – Detailed

Section 2. Background Information

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<tbody>
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<td>Country</td>
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<td>Fisheries region (e.g. MPA region)</td>
<td>Invalid name of person completing this form</td>
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<tr>
<td>Main types of fish caught</td>
<td>Invalid name of person completing this form</td>
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<tr>
<td>Species in the fisheries</td>
<td>Invalid name of person completing this form</td>
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Section 4. Processing at sea

| What by-products are generated? (select yes / no from the drop-down selector) |
|-----------------------------|-------------|
| Quills | Fish | Liver | Scales | Pedicles |

<table>
<thead>
<tr>
<th>What happens to the by-products (select yes / no from the drop-down selector)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All by-products are retained on-board</td>
</tr>
<tr>
<td>None of the by-products are retained on-board</td>
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<tr>
<td>Other, please specify</td>
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</table>

Section 5. By-product utilisation

<table>
<thead>
<tr>
<th>For what purpose are the by-products utilised? (select yes / no from the drop-down selector)</th>
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</thead>
<tbody>
<tr>
<td>By-products are utilised for human consumption</td>
</tr>
<tr>
<td>By-products are utilised for animal feed</td>
</tr>
<tr>
<td>By-products are utilised for other purposes</td>
</tr>
<tr>
<td>Other, please specify</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What methods are used to preserve the by-products (select yes / no from the drop-down selector)</th>
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</thead>
<tbody>
<tr>
<td>Chemical preservation</td>
</tr>
<tr>
<td>Freezing</td>
</tr>
<tr>
<td>Salting</td>
</tr>
<tr>
<td>Other, please specify</td>
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Section 6. Other Information

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<th>Other comments, or anything else of relevance to this questionnaire?</th>
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<td>Select</td>
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<tr>
<td>Other, please specify</td>
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</tbody>
</table>

List of by-products for reference

<table>
<thead>
<tr>
<th>By-products for reference</th>
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</thead>
<tbody>
<tr>
<td>All</td>
</tr>
<tr>
<td>Quills (medial fin and bone)</td>
</tr>
<tr>
<td>Scales</td>
</tr>
<tr>
<td>Heads</td>
</tr>
<tr>
<td>Trunks (branchios)</td>
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<tr>
<td>Other, please specify</td>
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Appendices
### Questionnaire 2 – Comprehensive version issued online

#### About the catch

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<tr>
<th>Regions</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
</tr>
<tr>
<td>Europe</td>
</tr>
</tbody>
</table>

#### Regions
- North America
- Europe
- North West Atlantic
- Australia (2)
- PNA Nations - Palau, FSM, RMI, Kiribati, Tuvalu, Nauru, Solomon Is, PNG, and Tuvalu

#### FAO fishing regions
- 18, 21, 27, 51, 57, 58, 67, 71, 77, 81, 88

#### Types of fish (main groups)
- Demersal (5)
- Pelagic (4)
- Shelfish (4)

#### Fish

#### Shellfish
- Dosidicus gigas - Humboldt or giant squid, Pandalus spp., Banana prawns, Tiger Prawns, Endeavour prawns,

#### For the species listed in the previous section, are any of these processed at sea? Yes (6) No (2) - but could be frozen

#### For species processed at sea, what type of processing is undertaken? Gutting (4) Filleting (4) Heading and gutting (5) Freezing (3)

#### Are by-products retained on-board? Yes (1) Partial (1) No (4)

#### Which by-products are retained on-board? Liver, Heads, Skin, Belly flaps / other trimmings, Frames backbonet

#### Reasons why by-products are not retained
- Human consumption (2)
- Fishmeal (1)

#### Why by-products are not retained
- Space, lack of on-board treatment/storage, crew has no time to process them, lack of market, limited/no demand, not cost-effective, short fishing season means we have to prioritise the more valuable parts of the catch, any and all of these apply.

### Appendices

#### Questionnaire responses (collated)

<table>
<thead>
<tr>
<th>Summarised responses (no’s in brackets show no of responses)</th>
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<tbody>
<tr>
<td><strong>Regions</strong></td>
</tr>
<tr>
<td><strong>Types of fish (main groups)</strong></td>
</tr>
<tr>
<td><strong>Fish</strong></td>
</tr>
<tr>
<td><strong>Shellfish</strong></td>
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#### Processing at sea

| Yes | No (2) - but could be frozen |
| 4 | |

#### By-products retained on-board?

<table>
<thead>
<tr>
<th>Liver, Heads, Skin, Belly flaps / other trimmings, Frames backbonet</th>
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</table>

#### Reasons why by-products are not retained
- Human consumption (2)
- Fishmeal (1)

#### Why by-products are not retained
- Space, lack of on-board treatment/storage, crew has no time to process them, lack of market, limited/no demand, not cost-effective, short fishing season means we have to prioritise the more valuable parts of the catch, any and all of these apply.
### Appendix III: Organisations and stakeholders contacted

#### At Sea Processors
- At Sea Processors Association
- European Association of Fish Producers Organisations (EAPO)
- European Fisheries Alliance
- Frozen at Sea Flags Association
- Global Tune Alliance
- Iceland Ocean Cluster
- Norway Fisherman's Association
- Parties to the Nauru Agreement (PNA)
- Scottish Fishermen's Federation
- The South African Deep-Sea Trawling Industry Association, SADSTIA
- Pelagic Freezer Trawler Association

#### RFMOs
- North East Atlantic Fisheries Commission (NEAFC)
- Northwest Atlantic Fisheries Organization (NAFO)
- South East Atlantic Fisheries Organization (SEAFIQ)
- Southern Indian Ocean Fisheries Agreement (SOIFA)
- South Pacific Regional Fisheries Management Organisation (SPRFMO)
- Convention on Conservation of Antarctic Marine Living Resources (CCAMLR)

#### Others
- Foundation – vessel listings
- Fishing Index
- Global Vessel Monitoring
- IMO
- Foundation for Fishers
- Association of Sustainable Fisheries
- World Maritime University

### Appendix IV: Motorised fishing vessels >24m LOA by country (continent)

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<th>Continent</th>
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<th>Asia</th>
<th>Europe</th>
<th>Oceania</th>
<th>Africa</th>
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<td>China</td>
<td>Norway</td>
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<td>Nigeria</td>
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<td>USA</td>
<td>Indonesia</td>
<td>Iceland</td>
<td>Pipa New Guinea</td>
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<td>Mauritania</td>
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<td>Chile</td>
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<table>
<thead>
<tr>
<th>Continent</th>
<th>% of motorised fleet that is &gt;24m LOA</th>
<th>Estimated no of vessels &gt;24m LOA</th>
<th>% of total no of motorised fleet</th>
<th>% applied to FAO estimate of 67,800</th>
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The countries or areas listed in this table are those with capture production of 200 000 tonnes or more in 2019. (FAO, 2020) (Food and Agriculture Organisation, 2021)
## Appendix V: Vessel size profiles by country in 2018 (OECD, 2022)

<table>
<thead>
<tr>
<th>Country</th>
<th>Vessel size range (LOA)</th>
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<td>New Zealand</td>
<td>4</td>
<td>4</td>
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### Vessel size profiles by country in 2018 (OECD, 2022)

<table>
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<th>Country</th>
<th>Vessel size range (LOA)</th>
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### Vessel size profiles by country in 2018 (OECD, 2022)

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<th>Country</th>
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### Appendix VI: Detailed yield data - Compiled from multiple references

<table>
<thead>
<tr>
<th>Species / group</th>
<th>'Guts'</th>
<th>Head:</th>
<th>Skinned fillets and skin off (min)</th>
<th>Skinned fillets and skin off (fixed Ave)</th>
<th>Skinned fillets and skin off (max)</th>
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<tbody>
<tr>
<td>Roundfish general (Cod (FAO)©)</td>
<td>8</td>
<td>16</td>
<td>15</td>
<td>20</td>
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<tr>
<td>Tuna (general)</td>
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<tr>
<td>Flatfish (general)</td>
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<td>squid</td>
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<td>8</td>
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### Appendix VII: Detailed nutritional composition data

#### PROXIMATE

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<th>Moisture</th>
<th>Protein</th>
<th>Fat</th>
<th>Ash</th>
<th>Format</th>
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<tr>
<td>% Wet weight</td>
<td>% Wet weight</td>
<td>% Wet weight</td>
<td>% Wet weight</td>
<td>% Wet weight</td>
</tr>
<tr>
<td>Cod</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste from filleting</td>
<td>72.0-79.5</td>
<td>14.3-14.3</td>
<td>1.3-1.6</td>
<td>1.8-3.9</td>
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<tr>
<td>Cod skin</td>
<td>35.8</td>
<td>14.3</td>
<td>0.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Cod Roe</td>
<td>71.5</td>
<td>23.5</td>
<td>2.5</td>
<td>1.4</td>
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<td>Cod trimmings</td>
<td>85.1</td>
<td>14.9</td>
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<td>0.8</td>
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<td>Salmon</td>
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<tr>
<td>heads</td>
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<td>Haddock</td>
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<td></td>
<td></td>
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<td>Heads</td>
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<tr>
<td>Visera</td>
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<td>1.8</td>
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<tr>
<td>Crab</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Tanner crab</td>
<td>76.7</td>
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<tr>
<td>King crab</td>
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#### Value

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<th>Value</th>
<th>MD</th>
<th>Value</th>
<th>MD</th>
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</thead>
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<tr>
<td>Crude protein</td>
<td>%</td>
<td>27.92 ± 0.06</td>
<td>27.89 ± 0.07</td>
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<tr>
<td>Fat</td>
<td>%</td>
<td>12.6 ± 0.18</td>
<td>12.1 ± 0.16</td>
</tr>
<tr>
<td>Ash</td>
<td>%</td>
<td>3.29 ± 0.13</td>
<td>3.36 ± 0.15</td>
</tr>
<tr>
<td>Calcium</td>
<td>%</td>
<td>0.52 ± 0.05</td>
<td>0.54 ± 0.05</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>%</td>
<td>0.44 ± 0.04</td>
<td>0.45 ± 0.04</td>
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</table>

### Composition of fish processing waste

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<th>Value</th>
<th>MD</th>
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<tr>
<td>Sodium</td>
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<td>0.61 ± 0.08</td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td>0.37 ± 0.04</td>
</tr>
<tr>
<td>Iron</td>
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<td>100.00 ± 42.00</td>
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<tr>
<td>Zinc</td>
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<td>82.00 ± 12.00</td>
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<td>Manganese</td>
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<td>0.50 ± 0.00</td>
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<tr>
<td>Copper</td>
<td>ppm</td>
<td>1.00 ± 1.00</td>
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*taken from Seafoods Chemistry, Processing Technology & Quality - Edited by F. Shahidi & JR Botta*
### Cyprinus carpi (freshwater)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tuna trimmings</th>
<th>Tuna frames</th>
<th>Tuna gills</th>
<th>Burrito</th>
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<tbody>
<tr>
<td>Moisture (g/100 g)</td>
<td>48.8 ± 1.35b</td>
<td>8.4 ± 0.01b</td>
<td>6.8 ± 0.04a</td>
<td>39.5 ± 0.30a</td>
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<tr>
<td>Water Activity (a)</td>
<td>0.81 ± 0.00a</td>
<td>0.85 ± 0.02a</td>
<td>0.83 ± 0.00a</td>
<td>0.88 ± 0.00a</td>
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<tr>
<td>Ash (g/100 g)</td>
<td>3.6 ± 0.78a</td>
<td>6.8 ± 0.03b</td>
<td>4.9 ± 0.06c</td>
<td>4.6 ± 0.13b</td>
</tr>
<tr>
<td>Fat (g/100 g)</td>
<td>3.7 ± 0.12a</td>
<td>0.1 ± 0.03a</td>
<td>0.5 ± 0.17c</td>
<td>0.4 ± 0.14a</td>
</tr>
<tr>
<td>Protein (g/100 g)</td>
<td>80.7 ± 0.18d</td>
<td>28.6 ± 0.08a</td>
<td>28.6 ± 0.08a</td>
<td>20.4 ± 0.16b</td>
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<tr>
<td>Carbohydrate (including fibre) (g/100 g)</td>
<td>5.9 ± 0.24c</td>
<td>7.6 ± 0.09a</td>
<td>7.4 ± 0.37c</td>
<td>10 ± 0.59</td>
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<tr>
<td>Energy (Kcal/100 g)</td>
<td>295.7 ± 1.46f</td>
<td>263.5 ± 0.46h</td>
<td>293 ± 1.66i</td>
<td>286 ± 1.26c</td>
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<tr>
<td>Phosphorus (mg/100 g)</td>
<td>20.0 ± 2.12d</td>
<td>127.0 ± 3.14f</td>
<td>127.0 ± 3.14f</td>
<td>527.7 ± 4.69a</td>
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<tr>
<td>Calcium (mg/100 g)</td>
<td>2085.3 ± 3.42a</td>
<td>5584.3 ± 8.23c</td>
<td>5584.3 ± 8.23c</td>
<td>3988.6 ± 4.18b</td>
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Results are presented as means and standard deviations. Analysis of variance (ANOVA) and Duncan test were used to significant differences between samples (P < 0.05). Means with the same superscripts are not significantly different from each other.

### Minerals

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<th>Cu</th>
<th>Zn</th>
<th>Mg</th>
<th>Mn</th>
<th>Ca</th>
<th>Fe</th>
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</tr>
<tr>
<td>Cod</td>
<td>2.4±3.36</td>
<td>1.2±1.40</td>
<td>0.1±1.02</td>
<td>6.4±3.67</td>
<td>3.4±3.03</td>
<td>1.4±1.83</td>
<td>3.8±3.95</td>
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<tr>
<td>cod skin</td>
<td>0.39</td>
<td>0.40</td>
<td>0.48</td>
<td>1.15</td>
<td>1.59</td>
<td>0.25</td>
<td>1.16</td>
</tr>
<tr>
<td>Cod Roe</td>
<td>2.4±1.01</td>
<td>0.87</td>
<td>2.8±2.49</td>
<td>0.8±1.0</td>
<td>0.1</td>
<td>2.4±1.0</td>
<td>3.4±1.0</td>
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<tr>
<td>cod trimmings</td>
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<td>1.67</td>
<td>0.4±0.2</td>
<td>0.28</td>
<td>0.1</td>
<td>1.89</td>
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</table>

**Pollock**

| Waste from | 1.65±2.34 | 1.75±2.27 | 0.47±1.33 | 1.35±0.85 | 0.48±0.04 | 1.0±1.5 | 3.6±4.15 | 0.1±0.4 |

**Haddock**

| Heads | 0.8±0.02 | 0.02 | 0.07 | 0.3±0.02 | 0.9 | 0.02 | 0.8 | 0.02 |

**Salmon**

| Heads | 1.65 | 1.04 | 0.8 | 2.4±0.02 | 1.07 | 0.1 | 1.70 | 0.02 |
| Viscera | 0.66 | 0.05 | 0.03 | 0.01 | 0.01 | 0.01 | 1.37 | 0.18 | 1.2±1.0 |

**Crab**

| Tanner crab | 2.2±0.83 | 1.02 | 3.75 | 2.12 | 1.63 | 1.0±1.0 | 4.1±1.0 | 2.0±1.0 |
| King crab | 0.3±0.15 | 0.15 | 3.07 | 1.65 | 0.02 | 0.02 | 0.02 | 0.02 |

**Charactetisation of Alaska Seafood Waste, University of Alaska, 1988**

<table>
<thead>
<tr>
<th>K</th>
<th>Na</th>
<th>Cu</th>
<th>Zn</th>
<th>Mg</th>
<th>Mn</th>
<th>Ca</th>
<th>Fe</th>
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<td>% dry matter</td>
<td>mg/kg dry matter</td>
<td>mg/kg dry matter</td>
<td>mg/kg dry matter</td>
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<td>mg/kg dry matter</td>
</tr>
<tr>
<td>Cod</td>
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<td>0.39</td>
<td>0.37</td>
<td>1.0</td>
<td>9.1</td>
<td>9.1</td>
<td>1.1</td>
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<tr>
<td>Heads</td>
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<td>21.0</td>
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<td>0.63</td>
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<td>0.03</td>
<td>0.03</td>
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**Advances in Seafood By-products, Alaska Sea Grant College Program, 2003**
### Mean data for the nutrient composition of by-product samples (head, gills, intestines, trimmings, bones, skin) of meagre and gilthead sea bream fishes in two different size classes (large and small).

#### By-Product Nutrient Composition

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<th>Mean</th>
<th>SD</th>
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<th>Mean</th>
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<tr>
<td><strong>Moisture</strong></td>
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<td>68.9</td>
<td>0.7</td>
<td>68.3</td>
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<td>73.2</td>
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<td>59.4</td>
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<td>15.79</td>
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<td>0.08</td>
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<td>7.89</td>
<td>1.28</td>
<td>13.08</td>
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<td>11.05</td>
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<td>18.52</td>
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<tr>
<td><strong>Moisture</strong></td>
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<tr>
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<td>16.08</td>
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<td>66.39</td>
<td>1.04</td>
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</table>

*ash, protein, fat, and carbohydrate contents are expressed on a dry weight basis; carbohydrates were calculated by difference; no statistically significant differences were observed between the different by-products, either between fish species or size classes.*

Aikaterini Kandyliari et al (2020)
## By-product nutrient composition

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<thead>
<tr>
<th></th>
<th>Head</th>
<th>Gills</th>
<th>Intestines</th>
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<td>Mean</td>
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<tr>
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<td>Sodium (Na)</td>
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<td>1.34</td>
<td>0.44</td>
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<tr>
<td>% RDA/AI</td>
<td>Calcium (Ca) *</td>
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<td></td>
<td>50</td>
<td>86</td>
<td>59</td>
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<td>Sodium (Na) *</td>
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<tr>
<td>% RDA/AI</td>
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<tr>
<td>% RDA/AI</td>
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<tr>
<td>% RDA/AI</td>
<td>Calcium (Ca)</td>
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<tr>
<td>% RDA/AI</td>
<td>Magnesium (Mg)</td>
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<td>0.86</td>
<td>0.43</td>
<td>0.28</td>
<td>0.29</td>
<td>0.64</td>
<td>0.31</td>
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</tbody>
</table>

* Mineral concentration was calculated as mg/g of dry matter. RDA/AI percentages for the content of 100 g of dried sample were calculated based on the following values: 1000 mg for Ca, 4700 mg for K, 329 mg for Mg, and 1500 mg for Na [31].

Aikaterini Kandyliari et al (2020)
Fish bone composition (lipid free dm)

<table>
<thead>
<tr>
<th>Content</th>
<th>Cod</th>
<th>Salmon</th>
<th>Herring</th>
<th>Mackerel</th>
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</thead>
<tbody>
<tr>
<td>Ash (g/100g)</td>
<td>3.9</td>
<td>4.7</td>
<td>4.4</td>
<td>6.9</td>
</tr>
<tr>
<td>Protein (g/100g)</td>
<td>58</td>
<td>58</td>
<td>58</td>
<td>44</td>
</tr>
<tr>
<td>Calcium (mg/100g)</td>
<td>19</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Iron (mg/100g)</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Zinc (mg/100g)</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Iodine (mg/100g)</td>
<td>59</td>
<td>25</td>
<td>95</td>
<td>13</td>
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</table>

Micronutrients of tuna back bone powder

<table>
<thead>
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<tr>
<td>Zinc</td>
<td>18</td>
</tr>
<tr>
<td>Iron</td>
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</tr>
<tr>
<td>Selenium</td>
<td>0.02</td>
</tr>
<tr>
<td>EPA/DHA</td>
<td>560</td>
</tr>
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</table>

Fishery and Aquaculture Department (FAD)

Amino acids

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<tr>
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<th>Mackerel</th>
</tr>
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<tr>
<td>Alanine</td>
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</tr>
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<td></td>
</tr>
<tr>
<td>Aspartic</td>
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<td>7.8</td>
<td>3.3</td>
<td>9.1</td>
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<td>7.7</td>
<td>1.5</td>
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<td>7.7</td>
<td>1.5</td>
</tr>
<tr>
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<td>5.86</td>
<td>7.7</td>
<td>1.5</td>
</tr>
<tr>
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<td>1.5</td>
</tr>
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<td>7.7</td>
<td>1.5</td>
</tr>
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<td>7.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Lysine</td>
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<td>7.7</td>
<td>1.5</td>
</tr>
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<td>7.7</td>
<td>1.5</td>
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<td>5.86</td>
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<td>1.5</td>
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<td>7.7</td>
<td>1.5</td>
</tr>
<tr>
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<td>5.86</td>
<td>7.7</td>
<td>1.5</td>
</tr>
<tr>
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<td>7.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Tyrosine</td>
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<td>5.86</td>
<td>7.7</td>
<td>1.5</td>
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</table>


dm: dry matter
### Appendices

#### Fatty Acids

**Fatty acid content (g/100 g) of the pooled by-products from meagre and gilthead sea bream fishes.**

Aikaterini Kandyliari et al. (2020)

<table>
<thead>
<tr>
<th>Fatty Acids</th>
<th>Meagre (Argyrosomus regius)</th>
<th>Gilthead Sea Bream (Sparus aurata)</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>p</th>
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</thead>
<tbody>
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<td>14:0</td>
<td>0.63</td>
<td>0.08</td>
<td>1.4</td>
<td>0.27</td>
<td>0.27</td>
<td>0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>15:0</td>
<td>0.08</td>
<td>0</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>16:0</td>
<td>3.15</td>
<td>1.85</td>
<td>0</td>
<td>0.18</td>
<td>0.27</td>
<td>0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>16:1</td>
<td>0.64</td>
<td>0</td>
<td>2.23</td>
<td>0.23</td>
<td>0.23</td>
<td>0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>17:0</td>
<td>0.05</td>
<td>0.01</td>
<td>0.08</td>
<td>0.02</td>
<td>0.02</td>
<td>0.39</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>18:0</td>
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</tr>
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<td>18:1</td>
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<td>0.22</td>
<td>1.34</td>
<td>0.01</td>
<td>1.34</td>
<td>0.01</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>18:2 n-6</td>
<td>0.02</td>
<td>0.07</td>
<td>0.07</td>
<td>0.02</td>
<td>0.07</td>
<td>0.02</td>
<td>&lt;0.05</td>
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<td>0.31</td>
<td>0.02</td>
<td>0.31</td>
<td>0.02</td>
<td>&lt;0.05</td>
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<td>0.07</td>
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<td>0.62</td>
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<td>0.62</td>
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<td>&lt;0.05</td>
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<td>0.13</td>
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<td>0.13</td>
<td>0.13</td>
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<td>0.09</td>
<td>0.03</td>
<td>0.09</td>
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<td>&lt;0.05</td>
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<td>0.04</td>
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<td>0.09</td>
<td>0.02</td>
<td>&lt;0.05</td>
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<td>0.04</td>
<td>1.1</td>
<td>0.13</td>
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<td>0.13</td>
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<td>0.04</td>
<td>0.1</td>
<td>0.02</td>
<td>0.1</td>
<td>0.02</td>
<td>&lt;0.05</td>
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<td>0.26</td>
<td>0.04</td>
<td>0.7</td>
<td>0.23</td>
<td>0.7</td>
<td>0.23</td>
<td>&lt;0.05</td>
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<td>0.53</td>
<td>0.15</td>
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<td>31.86</td>
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<td>5.26</td>
<td>0.86</td>
<td>&lt;0.05</td>
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Fatty acids are expressed as g/100 g of the lyophilized sample; p presents the differences between the two fish species.

#### Crustacea – various nutritional information

**Reference:** SeaFish (2008)

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<th>Determinant</th>
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<th>Crab (brown)</th>
<th>clean / crushed</th>
<th>units based on dry matter</th>
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* Calculated from organic carbon x 1.724
### Seafood by-product composition information (various species and determinants)

**Reference:** Seafish (2004)

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<td>92000</td>
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<td>3700</td>
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<td>2150</td>
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**Determination (Units) | Cod | Haddock | Mackerel | Nephrops | Crab | Whelks | Mussels |
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**Determination (Units) | White Fish A | White Fish B | White Fish C | Mackerel A | Mackerel B | Mackerel C |
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### Determination (units)

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### Appendices

This report was prepared by RS Standards.

Leading authors: Michaela Archer and Marcus Jacklin, RS Standards.

Additional images: David Russell.

David Russell, Melanie Siggis, and Sophie Wood, Friends of Ocean Action, provided guidance and review. Great thanks are also due to the valuable contributions of those who responded to the questionnaires.

Copy editing: Evan Jeffries of Communications INC.

Graphic design and layout: Matt Fidler of Communications INC.

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