Final Report

Resource Maps for Fish across Retail & Wholesale Supply Chains

Project code: RSC009-001 & RSC009-003
Research date: September 2009 to July 2010
ISBN: n/a
Date: September 2011
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Executive summary

In recent years, there has been significant interest in the issue of food and drink waste, and WRAP (Waste & Resources Action Programme) has highlighted the considerable economic and environmental impact associated with household food waste. WRAP is now extending this work to understand waste generation throughout food supply chains, and to identify approaches to minimising both the quantity of waste and its impact.

The current study is focused on retail and wholesale supply chains for fish, and presents resource maps for 17 individual finfish and shellfish species.

<table>
<thead>
<tr>
<th>Table A: Seafood species resource mapped</th>
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<tbody>
<tr>
<td>White Fish</td>
</tr>
<tr>
<td>Cod</td>
</tr>
<tr>
<td>Haddock</td>
</tr>
<tr>
<td>Monkfish</td>
</tr>
<tr>
<td>Pollock</td>
</tr>
<tr>
<td>Whiting</td>
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<tr>
<td>Plaice</td>
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</tbody>
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These resource maps illustrate the flow of materials through supply chains, and focus on the extent and causes of waste in the UK from primary processing to retailer shelf.

Most species of white fish undergo some processing at sea. Wastes both from processing at sea and discards are disposed of at sea, so they have no impact on UK waste disposal mechanisms. The results of the current study must therefore be considered as representing only a limited portion of the total UK fish supply chain, and must be used in conjunction with work from other supply chain sectors to understand fully the impact of UK seafood consumption.

Data Sources

The UK seafood supply chain comprises more than 500 individual seafood processors, nearly 100 wholesalers and over 600 fishmongers. The current study endeavoured to engage with a large and representative sample of this industry in order to produce a robust picture of UK supply chains. Data for resource maps was primarily derived from a two-pronged approach to data collection, which combined a series of detailed interviews with 20 companies and a telephone survey of an additional 270 companies. In total, this data collection comprised 190 processors, 60 wholesalers, 30 fishmongers and six large supermarkets.

A range of additional data sources was used and these are summarised in Table B. Using all these data sources, an approximate mass balance for supply chain inputs and outputs was produced.

<table>
<thead>
<tr>
<th>Table B: Data sources used to compile resource maps</th>
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</thead>
<tbody>
<tr>
<td>INPUTS Type Source of Data</td>
</tr>
<tr>
<td>Landings Existing data (MFA)⁷</td>
</tr>
<tr>
<td>Imports Existing data (customs codes)⁸</td>
</tr>
<tr>
<td>Aquaculture Existing data¹⁴,¹⁶</td>
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</table>

Non-edible inputs and unavoidable waste

For all species of fish, the whole animal contains a high proportion of non-edible content. This is approximately 58% for white fish, such as cod, but can be as high as 88% for shellfish such as scallop. This non-edible material must be removed as waste or co-products at some stage within the supply chain. A key aspect of our resource map construction has therefore, been to estimate the quantity of non-edible material entering supply chains, to provide an indicative view on expected unavoidable waste and co-products. This proportion of non-edible input is
heavily influenced by the format of inputs; for example, a fish landed whole will result in considerable by-products being produced during processing, whereas an imported fillet will not. All available information on input (and export) formats has been captured within the resource maps, but there are considerable gaps in data availability.

By producing an estimate of expected non-edible material entering each species supply chain, the project aim was to differentiate between and quantify co-products, unavoidable and avoidable wastes.

**Data Extrapolation & Data Limitations**

The following estimates of waste and co-product arisings form a key feature of the resource maps:

- Estimates of average percentage processing waste and co-product arisings; either by species or by fish type.
- A species-specific extrapolation of UK-wide processing waste and co-products. A combined figure for waste and co-products is presented within the resource maps; where possible this figure is broken down to indicate the proportion of this material which is utilised as co-products.
- Estimates of retail ‘waste’.

The high level of variability in processing operations makes it difficult to extrapolate information across the whole industry. Many companies have very diverse and variable operations, with even small companies processing several species of fish and producing a complex range of products. The majority of companies could only provide figures on total waste and co-product volumes, rather than on a species-specific basis, and respondents were often unable to give an accurate view of the proportions of different formats of fish entering their operations. These factors made the task of generating accurate species-specific information challenging.

Extrapolations to provide estimates of industry-wide waste and co-products arisings were either carried out by ‘fish type’, or derived from data of companies that predominantly processed one species of fish. For example, data on all white fish species have been combined to provide an estimate of the average levels of processing waste arising within white fish processing companies. Extrapolated averages of waste arisings for shellfish species are based on data obtained from a small sub-set of single species processors.

**Resource Map Conclusions**

The resource maps present a summary of material flows in UK supply chains for individual species of fish. Comments are made on the factors which contribute to waste and co-product generation within these supply chains, and the major mechanisms used for co-product utilisation or waste disposal are highlighted. As noted above, estimates of waste and co-product generation within both processing and retail form a key feature of the resource maps.

Table C summarises the estimates of waste and co-product volumes produced in this study, and references these figures against non-edible inputs. It is noteworthy that in many cases the estimated values of waste and co-products are considerably lower than expected from the non-edible inputs. A key factor in this discrepancy is that, for many species, the export of large volumes of un-processed products results in this non-edible material being manifest outside the UK supply chain.

It must also be noted that, for some species, the combined figure for processing co-products and wastes cannot be broken down into material which is utilised as a co-product, generating value for the producer, and material which is disposed of as waste.
The key findings from the resource maps are as follows:

- Total volumes of waste and co-products generated within processing were estimated at 133,100tpa. As discussed above, this figure cannot be robustly sub-divided into wastes and co-products for all species.
- 105,200tpa waste and co-products were derived from finfish processing. The majority of this material is sold by processors to fishmeal plants and is therefore a valuable co-product.
- 27,900tpa were attributed to shellfish processing. This estimate includes figures for scallop, crab and nephrops only; robust estimates for cold-water prawn, warm water prawn and mussel supply chains could not be derived but are believed to be low.
- This total figure for shellfish cannot be readily divided into co-products and wastes. This distinction is challenging for species such as crab and scallop where, although material may end up being used in markets such as aggregates, it is often viewed as a waste by the producer as they have to pay for its removal.
- The majority of waste and co-products created in the seafood-processing sector is unavoidable, derived from non-edible components.
- A processor’s waste and co-product generation is highly dependent on the operations carried out and the format of fish processed; for example, whether raw material is fish or fillets.
- Filleting produces the highest volume of waste and co-products within finfish processing.
- The highest quantity of waste and co-product produced by shellfish processors is from removing the product from the shell; this is known as picking, shucking or peeling, dependent on species.
- Quantities of avoidable waste within processing cannot be estimated, as these relatively small volumes are 'lost in the noise' of the much higher non-avoidable arisings.
- A comparison of edible inputs and product volumes indicates that avoidable waste arisings within processing are generally low.
- Average figures for retail waste of 5% for fresh fish and 1% for frozen fish were derived from multiple retailers and used for all species; this provides an overall estimate of 6,800tpa of retail waste for the 17 species of interest. Note that for the purposes of the report retail waste is defined as products that do not sell...
at full-price, and so are considered as a commercial waste to the retailer, it does not necessarily reflect the amount of material that goes for final disposal.

- The majority of retail waste will be avoidable.

Summary of Seafood Processing

Within the processing sector the greatest issue experienced by some companies, predominantly shellfish processors, is finding outlets for their by-products, especially the large volumes of shell and viscera, that are both compliant with legislation and economically viable. This issue is often exacerbated by the remote, rural locations of these companies, as no treatment facilities may be available locally.

In addition, the following conclusions can be derived on waste generation, treatment and minimisation within UK processing:

- Detailed waste audits would be required to accurately quantify avoidable waste arisings in different types of processing operations.
- Initiatives to maximise yield are common within the industry, and processes such as filleting are highly effective at extracting the maximum edible yield. This is driven by a strong view that fish is too valuable a commodity to waste.
- Commonly used mechanisms to minimise waste include staff training, use of catch trays to prevent fish falling to floor and use of rejected (e.g. wrong size) fish in alternative products.

The well-established market for finfish by-products in fishmeal operations has been described above. However, our study also revealed a range of other mechanisms for co-product utilisation, which are utilised by the seafood industry. These include:

- Sale of dried fish heads to African markets.
- Sale of fish frames for production of flavour in other fish products.
- Use of scallop or crab shell in decorative applications or as aggregate.

Retail ‘Waste’

The figures of 5% ‘waste’ for fresh fish and 1% for frozen used in the resource map estimates were obtained from figures provided by the six multiple retailer participants. These retailers do not routinely monitor the quantity of fish products that are sent for final disposal, so this figure is derived from an estimate of commercial waste; i.e. products that do not sell at full price and are therefore viewed as a ‘waste’ to the retailer. It is important to stress that through strategies such as the use of mark down and discounted sales to staff, the figure for final back-of-store waste that requires rendering or final disposal would be expected to be significantly lower. However, this 5% figure includes a level of estimation from retailers, and also does not account for material derived from processing on fish counters. Due to considerable variability in data, no average value for waste from fishmongers, who account for about 12% of UK seafood retail, has been derived.

All multiple retailers emphasised the measures they are taking to minimise waste, where the most common approaches were control of stock ordering, use of markdowns, optimised shelf stacking and monitoring of storage temperature.

Driven by both the need to comply with Animal By-Products Regulations (ABPR), and a focus on diverting waste from landfill, retailers are utilising a range of outlets for this material. The most common outlet is rendering, with material also used in production of pet food.

Packaging Usage

Project participants were asked about the types of packaging used within their operations, disposal mechanisms and measures adopted to reduce packaging waste. This work produced the following conclusions:

- A wide range of initiatives is underway at all stages of UK seafood supply chain to minimise the impact of packaging.
- Initiatives encompass all aspects of the waste hierarchy, from diverting waste from landfill to minimising the quantity of packaging used.
- Many initiatives are driven by retailers looking to meet demanding targets under the Courtauld Commitment and to address consumer concerns about excessive packaging. Due to the strong relationship, the big multiples have with their key suppliers, this can lead to adoption of waste reduction mechanisms throughout the supply chain.
There are examples of packaging reduction work undertaken independently by small processors. These companies are often driven by the incentive of reducing the cost associated with both the purchase and disposal of packaging.

Widely used packaging minimisation initiatives include light-weighting, often through a complete rethink of packaging materials and design, and increasing recycled content.

Disposal of contaminated packaging can present problems, as this must be disposed of in compliance with ABPR and may therefore not be readily recyclable.

Treatment of expanded polystyrene (EPS) fish boxes can be problematic due to the large volumes required to make compaction, and therefore recycling, commercially viable. Several big retailers are reducing their use of EPS; however, the preferred alternative for transit packaging is unclear. There are signs that some of the larger manufacturers are starting to use reusable transit systems.

**Water Usage**

All participating processors were asked about levels of water usage, effluent generation and approaches implemented to minimise this usage. Information was only requested on a high-level, company-wide basis as it was beyond the scope of this work to examine water use by process or species. This work produced the following main conclusions.

- Many companies are concerned about the high water costs they are incurring.
- Most companies could not accurately quantify their current usage.
- The majority of processing companies (73%) reported that they were undertaking measures to minimise water usage.
- The most common water minimisation measures used were simple low cost options such as staff training (e.g. to turn off taps when not in use), use of catch baskets to reduce waste to drain, and use of flow restrictors.

If properly implemented, the water minimisation approaches described have potential to deliver considerable water savings; however, it was not possible to quantify the derived benefits due to the low availability of robust data on water usage.

Indicative results for water usage were obtained for specific areas of seafood processing; notably white fish, crab and scallop processing. These results showed a high level of variability within the white fish sector, with filleting and thawing appearing to be major water using stages. A comparison of figures for crab and scallop indicates that crab processing, which includes cooking in water, is much more water intensive than the largely dry scallop preparation process. Further work would be required to establish whether the small data set obtained within this work is indicative of these sectors overall.

**Carbon & Economic Impact**

For seven species, case studies estimating the carbon and economic impacts of notional supply chains and the resulting waste were developed. These case studies examined the supply chain, from capture to final consumer, and both provide a view on the key factors that contribute to greenhouse gas (GHG) emissions and illustrate the level of variability between supply chains.

- Results generated through these case studies reveal a wide range in GHG emissions, from 960kg CO₂e / tonne to 13,410kg CO₂e / tonne.
- Primary production, whether in fish capture or fish farming, is typically responsible for the largest share of GHG emissions.
- Variation in gear and practices used by the fleet have a very significant influence on the impact from fishing; a notable contrast is the low emissions contribution made by the pelagic trawl (mackerel) compared to the shellfish trawl (scallops and nephrops).
- Processing generally makes a small contribution to overall emissions, with the exception of those products processed to a high-level e.g. smoked mackerel or cooked crab.
- Transport-related emissions are typically higher for imported and exported products and those from remote rural areas (as in the case of farmed salmon).
- Refrigeration makes a very small contribution to overall emissions.
- Retail contributes to the overall emissions; however, due to a lack of seafood-specific data, trends commented on within this work should be treated with caution.
- Utilisation of co-products can have a noticeable impact on the emissions burden of a product; for example, use for fishmeal or markets for shell have a lesser impact than landfill.

The high variability between the impacts of different supply chains illustrates that it is not possible to assign a simple figure for the average carbon or economic impact of a tonne of seafood waste, or even a tonne of waste of one specific species. However, this work provides strong evidence of the factors, most noticeably primary production, which influence the GHG impact of fish products and wastes.
**Recommendations**

This report makes a number of recommendations for measures that could help seafood supply chains reduce the environmental impact of their operations.

A key finding of this work is that, due to both highly variable operations and high arisings of unavoidable by-products, it is impossible to quantify the avoidable waste arisings within processing. It is therefore recommended that:

- A series of detailed waste audits at companies be carried out to assess and benchmark the level of avoidable waste produced by key operations, such as filleting, shucking or picking.

Several recommendations relate to approaches which could help shellfish processors exploit potential markets for shell and move material up the waste hierarchy. These approaches could prove environmentally beneficial by converting ‘problematic wastes’ into valuable co-products, and could also deliver economic advantages to processors.

- Clarify the definition of ‘free-of-flesh’ shell: ABPR state that free-of-flesh shell can be used in other applications; however, within the UK it is currently not clear what material meets this classification.
- Develop a Quality Protocol and PAS for shell to enable this material to be classified as a product rather than as a waste.
- Develop markets for shell products. Potential applications include aggregates, filter media or for decorative purposes.
- Use the current EU revision of ABPR as an opportunity to apply a risk-based approach to reconsider how shell is categorised within the legislation. For example, this may provide scope to exclude free-of-flesh shell from the scope of the regulation.
- Review geographical spread of ABPR-compliant facilities, such as in-vessel composting and AD, for treatment of shellfish flesh wastes. Identify areas where significant volumes of suitable material are available but current treatment infrastructure is limited.
- Develop mechanisms to encourage installation of cost effective, ABPR-compliant facilities in these areas.

Additional recommendations relate to approaches which could be adopted to enable the seafood processing industry to manage and minimise their water usage.

- Promote proactive monitoring of water usage. Encourage and incentivise companies to install individual process water meters.
- Promote awareness of cost savings which can be achieved by adopting simple, low cost water reduction measures.
- Encourage take-up of initiatives such as the Federation House Commitment.
- Benchmarking of process water usage. Carry out water audits at a range of companies to record process-specific water usage and effluent generation for a range of operations (e.g. for filleting or cooking of crab), and to provide an up-to-date view of average and best practice water usage.

In relation to packaging usage, a key finding was that many companies are moving away from the use of expanded polystyrene fish boxes. In order to enable companies to make informed decisions on the best options for transit packaging the following recommendation is made:

- A study of the relative life cycle impacts of a range of fishbox options, including reusable transit systems should be carried out, to provide a clear view of the preferred packaging approach for transportation of fish.
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Glossary & Abbreviations

- **Animal By-Products (ABP)** – Products of animal origin (including fish) which are not intended for human consumption. Most fish by-products are classified as Category 3 ABP; see entry below.

- **Animal By-Products Regulations (ABPR)** – Refers to the European Regulation No. 1774/2002 and the related 2005 UK regulations (SI 2005, No. 2347). These regulations categorise ABP according to risk and state requirement for storage, disposal and use of these materials. Note this has since been updated by European Regulation Nos. 1069/2009 and 142/2011.

- **Avoidable waste** – Edible parts of animals which could be utilised for consumption but end up discarded. Within the supply chain defined by this report, this will include edible portions which are not removed during processing, if the maximum yield is not obtained. May also arise through quality deterioration, or from out-of-specification products.

- **By-products** – unavoidable secondary products from processing of fish. By-products which have a negligible or negative value to the producer will generally be considered as waste. A by-product which has value can be defined as a co-product. For example, crab shell is a by-product which is inevitably produced by crab processors. A crab processor may view this shell as a co-product if they derive a value from it or as a waste if they have to pay for its disposal. See also co-products.

- **Category 3 ABP** – Low risk material fit, but not intended for, human consumption. Within the UK, the vast majority of fish and shellfish waste (including shell) from processing is classified as Category 3. Category 3 material may be treated by a range of methods; incineration, rendering, AD or composting and subject to meeting minimum pasteurisation standards, is appropriate for use as pet food.

- **Co-products** – Unavoidable secondary products of fish processing, which cannot be utilised for human food products but have a marketable value to the producer. Within the finfish industry, the majority of non-edible components are considered to be valuable co-products, and are sold to fishmeal plants for conversion into animal feed products. Non-edible material may be viewed as a co-product by one fish processor, but as a waste by another depending on the availability of outlets for the material. See also by-products.

- **Demersal fish** – see ‘White Fish’.

- **Disposal routes** – Refers to the method by which wastes from processors and retailers are treated. In this study, it does not necessarily mean that material is sent to landfill, but also includes methods which are more accurately classified as recovery; for example composting, AD or rendering. The emphasis of this terminology is that the material is viewed as a waste, and the route used is waste disposal from the perspective of the material producer. They are also generally methods which incur a cost.

- **Expanded Polystyrene (EPS)** – Packaging material commonly used for production of fish boxes for bulk transport of fish.

- **FAO** – Food and Agriculture Organisation of the United Nations.

- **Fishmeal** – A high protein nutrient-rich animal feed ingredient, which may be produced either from industrial fish or from fish processing by-products. Industrial fish are those which are caught for the purpose of using in fishmeal rather than primarily for human consumption. They tend to be different species of fish to the major ones caught for human consumption, for example blue whiting.

- **MFA** – Marine and Fisheries Agency.

- **Multiples** – A term used to describe the major supermarkets that have multiple sales units within the UK. In this report it predominantly refers to the six supermarkets that participated in the research.

- **Pelagic fish** – Fish that spend most of their life swimming in the water column as opposed to resting on the bottom.

- **Possibly avoidable waste** – This encompasses material which may be considered edible by some people. For example, monkfish cheeks are not generally eaten within the UK but are considered a delicacy in other cultures. A second category of possibly avoidable waste is material which is edible but is not currently considered economically viable to use. An example of this type of waste may include crabmeat contained within the crab ‘purse’. Although edible, this meat tends to be both difficult to recover and of lower value, and is therefore not cost effective for processors.

- **Rendering** – Treatment method for animal by-products whereby material undergoes transformation into a variety of products; most notably protein meals and oils. Protein meal was historically used as animal feed, but this option is now more limited due to the ABPR. Retail ‘waste’ – the figures for retail waste were obtained from figures provided by the six multiple retailer participants. Retailers do not routinely monitor the quantity of fish products that are sent for final disposal, so this figure is derived from an estimate of commercial waste; i.e. products that do not sell at full price and are therefore viewed as an economic ‘waste’ to the retailer. It is important to stress that through strategies such as the use of mark down and discounted sales to staff, the figure for final back-of-store waste that is sent for rendering or final disposal to landfill would be expected to be significantly lower.
Unavoidable waste – Waste arising in seafood supply chains which is not edible under normal circumstances, for example bones, shell or viscera. These materials should not be confused with avoidable waste which arises through a failure to obtain the maximum yield during processing.

White fish – Also known as demersal fish. These are fish which, in contrast to pelagics, live near or on the bottom of lakes and oceans. They contain a much lower oil content than pelagics.

WRAP - Waste & Resources Action Programme.

WPR – Waste Prevention Review carried out by Envirowise to identify areas for waste reduction within companies’ operations.
1.0 Background and Introduction

1.1 Project introduction
Considerable recent work has examined the environmental and economic impact of waste food. It is within this context of developing mechanisms to reduce both the occurrence and impact of waste that the current work has been undertaken. This work focuses on retail and wholesale supply chains for fish, and examines waste creation and resource utilisation from primary processing to retail. The key objective is, through generation of species-specific resource maps, to understand both the current reasons for waste creation and identify approaches for waste minimisation. Projects to produce resource maps in other sectors of the food industry, including meat and meat products, have been undertaken concurrently with this work.

1.1.1 Whole supply chain waste
It is important to treat the findings of this project within the context of the entire supply chain for fish. Waste arisings from fishing, aquaculture, foodservice and consumer waste are not considered here, but will each contribute a considerable amount to the overall picture of UK fish waste generation.

Consumer waste: Work by WRAP has quantified the considerable financial and carbon impacts associated with household food waste. In comparison to some food categories, high value products such as meat and fish result in relatively low levels of consumer waste. However, WRAP’s study still showed that household disposal of fish and shellfish amounted to 43,000tpa with a total value of £250m. The majority of this waste (32,000tpa) was shown to be avoidable, created by products not being used in time or too much food being cooked.

Discards: From a study conducted in 2005, it has been estimated by the Food and Agriculture Organisation (FAO) that around 7.3 million tonnes of whole fish (around 8% by volume of the global catch) is discarded worldwide every year in commercial fisheries. Based on previous FAO studies, current estimates suggest a reduction in discards and discard rates at the global level.

Accurate data on UK discards is hard to come by, as the situation is both highly complex and rapidly changing. Data on discards ideally should be estimated based on fishery-specific information, as some fisheries have very different discard rates to others. Production of this information is outside the scope of this study. It is also worth noting that not all fish discarded through fishing return to the sea dead, and those that do can have a positive impact on the food chain; making bold assertions regarding waste can be difficult to substantiate. That said, discard is a real issue for the UK fishing industry and one that fishermen, scientists and managers are working hard to resolve.

The reasons for discarding fall into two main categories: either what has been caught has little or no market value, or the fish are discarded because of management regulations. The levels of these discards can vary widely between fisheries. Some fisheries discard very little whilst others discard more than they retain. Some discards are not problematic, as in some cases the fish can be returned to the sea and survive; for example crabs, lobsters, sole, plaice and dogfish all have high survival rates. Otherwise discards account for a large amount of the waste of the fishery resource. This is mainly as a result of the fisheries management scheme and addressing this is beyond the scope of this project.

In the UK considerable efforts are currently underway to reduce discards, with measures including improvements to the design of fishing gear in order to minimise the catch of prohibited or unwanted fish, introduction of innovative conservation measures, fishery closures and observer programmes. Many of these efforts are a result of legislative changes; however, a large number have been initiated by the fishing industry. The EU Commission is increasingly accepting that some of the UK initiatives have potential applicability over a much wider geographical area. Modifications to EU regulations to reduce discard of over-quota fish are also under consideration.

Processing at sea: Most species of white fish undergo some processing at sea. Seafood’s 2001 waste study provided estimates on the ratio of gutting waste according to the species. For cod, it can vary between 8 and 22% of the whole weight of the fish, but it is typically around 16%. There are no published ratios for other white fish species, so the figure for cod is generally applied to all white fish. Pelagic and shellfish generally do not receive any processing at sea apart from a proportion of the nephrops catch, which typically have their head and claws removed and discarded at sea.

It should be noted that wastes both from processing at sea and discards are disposed of at sea, so they have no impact on UK waste disposal mechanisms.

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Image: WRAP Material change for a better environment

Resource Maps for Fish across Retail & Wholesale Supply Chains
Aquaculture: A 2008 report by the Scottish Aquaculture Research Forum (SARF) provides recent information on waste management in the Scottish salmon farming industry. It gives an estimated figure of 9,300 tonnes of waste generated annually by Scottish aquaculture. This figure includes all types of aquaculture waste, including approximately 3,200tpa of fish mortalities and 3,300tpa of waste plastic. Fish are generally gutted within aquaculture before entering the UK processing sector. An estimate of this waste is not included within the SARF figures, but will represent approximately 16% by weight of the fish produced.

The results of the current study must therefore be considered as representing only a limited portion of the total UK fish supply chain, and must be used in conjunction with work from other supply chain sectors to fully understand the impact of UK seafood consumption.

1.2 Context of work

In recent years disposal of waste has become increasingly difficult and costly for the seafood industry. The impact of legislation, such as the Animal By-Products Regulations (ABPR), means that historical methods of waste disposal are no longer permitted and the industry faces the challenge of identifying, and meeting the costs of, new methods.

Production of seafood products inherently creates large quantities of waste and co-products, as the edible portion of many species, especially shellfish, is low. Removal of the edible portion from the non-edible portion is a key stage in many supply chains, and results in the generation of large quantities of predominantly unavoidable by-products.

Short shelf lives of seafood also contribute to waste generation, and the requirement for refrigerated (or frozen) storage and transport imposes requirements for thermally insulating packaging. Considerable amounts of waste packaging, including the traditional expanded polystyrene (EPS) fishbox, result from this need to prevent product spoilage. Where packaging is contaminated with fish, recyclability can be limited.

Industry water use is also a key issue. Many essential processing stages, such as water thawing and filleting, are both water dependent and generate effluent. Again, legislation has led to escalating costs that will require the industry to rethink its approach to water use.

This project aims to investigate waste generation, co-product utilisation and water usage within seafood supply chains, from processing to retail, and to present the results in terms of resource maps for key seafood species. The specific objectives of the project are:

- to develop a method to quantify the amount of fish and shellfish waste arising in the UK retail and wholesale supply chain;
- to quantify the waste arisings in terms of tonnage, economic value and carbon equivalents (and for products to identify avoidable and unavoidable waste);
- to quantify the amount of water used by the fish and shellfish industry;
- to identify the waste (product and packaging) profiles of the 19 species identified for the study;
- to identify waste profiles in terms of primary, secondary and tertiary packaging, and by material;
- to identify how product loss and waste is managed along the supply chain, and where it ends up;
- to consider potential impacts on reducing household food and packaging waste;
- to provide an indication of waste levels at UK level by country using actual data sets as well as market share and/or population data; and
- to identify good practice that will lead to improved resource efficiency in the fish and shellfish manufacturing industry.

Considerable previous work has been carried out to understand waste generation and water usage. Where appropriate, these previous findings have been incorporated. The current project goes beyond this previous work by looking to understand material flows on a species-specific basis. Additionally, work has identified examples of best practice, where initiatives either to minimise waste or to move material up the waste hierarchy have been undertaken.

1.2.1 Avoidable and unavoidable wastes

The aim of differentiating between unavoidable waste and avoidable waste, which could potentially be prevented, is a key focus of the current work. As highlighted above, many fish species contain a high proportion of non-edible components, which must be removed at some point within the supply chain. The project considers the volume of unavoidable waste and co-products expected within supply chains, to correlate with the non-edible portion of that species. It must be noted that in many supply chains this non-edible material is a valuable co-product, which is utilised by the fishmeal industry and therefore is not considered to be a waste.
Processing can also create possibly avoidable wastes, comprising parts of the fish or shellfish that are technically edible, but currently not marketable for human consumption or commercially viable to remove. For example, mince production from fish frames is not generally undertaken in fish processing. Likewise, although considerable effort has been taken to maximise yields of edible crab meat, recovery of small amounts of residual material cannot be effectively achieved. Although difficult to quantify, it can generally be assumed that these types of possibly avoidable wastes are minimal.

Avoidable wastes can include parts of the animal that may be utilised for consumption, but end up discarded. It also includes any excess edible portion that may be left behind on the fish and shellfish, i.e. if the maximum yield is not removed. Other causes may be defect or out-of-specification products, and losses through quality deterioration.

1.3 Project scope
This project focuses on waste generation and water usage within seafood supply chains, from primary processing to retail. Figure 1 summarises the supply chain steps that are included and excluded. It also highlights areas where, although outside the project scope, existing data sources have been used to construct the resource maps.

Figure 1: Summary of project scope

The focus of this project is on the species listed within Table 1. These 19 species represent the major types of finfish and shellfish of significance to UK markets.
### Table 1: Product categories by industry sector

<table>
<thead>
<tr>
<th>Demersal</th>
<th>Pelagic</th>
<th>Finfish Aquaculture</th>
<th>Shellfish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cod</td>
<td>Herring</td>
<td>Salmon</td>
<td>Cockles</td>
</tr>
<tr>
<td>Haddock</td>
<td>Mackerel</td>
<td>Trout</td>
<td>Crabs</td>
</tr>
<tr>
<td>Monkfish</td>
<td>Tuna</td>
<td></td>
<td>Mussels</td>
</tr>
<tr>
<td>Pollock</td>
<td></td>
<td></td>
<td>Nephrops</td>
</tr>
<tr>
<td>Whiting</td>
<td></td>
<td>Warm Water Prawns</td>
<td></td>
</tr>
<tr>
<td>Plaice</td>
<td></td>
<td>Cold Water Prawns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scallops</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Whelks</td>
<td></td>
</tr>
</tbody>
</table>

### 1.4 Data collection

A two-pronged approach to data collection was adopted by the project in order to obtain both depth and breadth of information across all species of interest:

- **Detailed interviews**: A series of detailed interviews was carried out with 20 companies. This selection of companies included primary and secondary processors with a wide variation in operations, six multiple retailers and a wholesale market.
- **Telephone survey**: A 15-minute telephone survey was developed to obtain information on companies’ major operations and waste generation. The companies, 270 in total, included primary processors, secondary processors, wholesalers and small retailers.

Both approaches to data collection adopted a similar approach and incorporated many of the same questions. The major questions included in both are listed below:

- type of operations;
- species of fish handled;
- formats of raw materials handled;
- processing operations carried out;
- quantities of materials handled (by species);
- quantities of waste and co-products generated;
- main reasons for waste generation;
- problems with waste disposal;
- waste disposal or co-product utilisation mechanisms used;
- waste minimisation measures undertaken;
- packaging types used; and
- water consumption (high level company-wide usage).

Interpretation of the overall data set derived by combining these two approaches is discussed in considerable detail later in this report. However, it is worth noting that accurate information on both waste arisings and water usage was frequently not available.

#### 1.4.1 Telephone survey

The time restrictions of the telephone survey coupled with the need to record simple answers meant that this approach was structured in terms of mainly simple questions with ‘yes or no’ answers. Companies were also asked only to provide information on their most significant operations, a maximum of four species of fish and the two most significant forms of packaging.

Due to the complexity of many companies’ business operations, it was not considered realistic to request all data on a species-specific basis. For example, details of processing operations were requested for a type of fish (e.g. white fish) rather than for each species. Waste quantities were also only requested by fish type; however, this decision was primarily driven by preliminary results from detailed interviews, which indicated that companies rarely have this information on a species-specific basis.

Table 2 provides a breakdown of the responses obtained from the telephone survey.
Table 2: Telephone survey responses by species and type of company

<table>
<thead>
<tr>
<th>Species</th>
<th>Primary processor</th>
<th>Secondary processor</th>
<th>Wholesaler</th>
<th>Fishmonger</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>White fish</td>
<td>65</td>
<td>35</td>
<td>43</td>
<td>24</td>
<td>155</td>
</tr>
<tr>
<td>Cod</td>
<td>37</td>
<td>23</td>
<td>22</td>
<td>16</td>
<td>90</td>
</tr>
<tr>
<td>Haddock</td>
<td>57</td>
<td>29</td>
<td>27</td>
<td>17</td>
<td>120</td>
</tr>
<tr>
<td>Monkfish</td>
<td>7</td>
<td>2</td>
<td>10</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Pollock</td>
<td>1</td>
<td>61</td>
<td>8</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>Whiting</td>
<td>12</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Plaice</td>
<td>5</td>
<td>6</td>
<td>10</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>Pelagic fish</td>
<td>16</td>
<td>23</td>
<td>10</td>
<td>5</td>
<td>46</td>
</tr>
<tr>
<td>Herring</td>
<td>11</td>
<td>14</td>
<td>9</td>
<td>5</td>
<td>34</td>
</tr>
<tr>
<td>Mackerel</td>
<td>11</td>
<td>12</td>
<td>7</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>Tuna</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>Salmon &amp; trout</td>
<td>41</td>
<td>29</td>
<td>23</td>
<td>9</td>
<td>90</td>
</tr>
<tr>
<td>Salmon</td>
<td>41</td>
<td>29</td>
<td>23</td>
<td>9</td>
<td>90</td>
</tr>
<tr>
<td>Trout</td>
<td>25</td>
<td>10</td>
<td>18</td>
<td>8</td>
<td>53</td>
</tr>
<tr>
<td>Shellfish</td>
<td>61</td>
<td>28</td>
<td>24</td>
<td>14</td>
<td>116</td>
</tr>
<tr>
<td>Cockles</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Crabs</td>
<td>31</td>
<td>14</td>
<td>13</td>
<td>6</td>
<td>56</td>
</tr>
<tr>
<td>Mussels</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Nephrops</td>
<td>18</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>Warm Water Prawns</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Cold Water Prawns</td>
<td>6</td>
<td>9</td>
<td>6</td>
<td>5</td>
<td>24</td>
</tr>
<tr>
<td>Scallops</td>
<td>19</td>
<td>2</td>
<td>10</td>
<td>4</td>
<td>34</td>
</tr>
<tr>
<td>Whelks</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
</tbody>
</table>

a) Companies identified themselves by major types of operation (may select multiple types). For example, a company may identify itself as both a primary and secondary processor. However, all operations may not be relevant for all species processed; a white fish processor may carry out primary operations on a wider range of fish than secondary.

b) All respondents completed questions on a maximum of two fish types and a maximum of two species for each type. Species generally selected based on volumes processed.

1.4.2 Detailed interviews

In contrast to the telephone survey, detailed interviews included a series of more open questions to encourage companies to provide more in-depth information on, for example, issues experienced with waste management and measures adopted on waste minimisation. Companies were also asked to provide information on all types of fish which they processed and all types of packaging used.

As noted above, in addition to processing companies, detailed interviews were also carried out with six multiple retailers. Preliminary discussions with these retailers led to the conclusion that species-specific information on waste generation was generally not readily available. These interviews therefore focused primarily on the reasons for waste generation and mechanisms undertaken to minimise this waste.

1.4.3 Waste prevention reviews

Companies participating in this study were asked whether they were interested in a waste prevention review (WPR), to assess areas for improvements in waste management in their business operations. These WPRs involved an Envirowise representative visiting the companies’ premises to carry out an assessment of existing operations, and identify potential opportunities to improve waste management and realise cost savings. A total of four companies, three processors and a wholesale market completed these reviews, and the results are included in this report. The focus of all three WPRs carried out for processors was on identifying opportunities to improve water efficiency, as this was the area that Envirowise was keen to target.
2.0 Resource maps for fish

2.1 Resource map structure

Resource maps generated for 17 species of fish and shellfish are presented in this report. These resource maps incorporate both existing data and data derived from the current study. Due to lack of data it was not possible to produce resource maps for cockles and whelks.

The quantities of inputs to and outputs from each supply chain are also summarised in simple charts.

2.1.1 Data sources used

The following major sources of existing data have been used in conjunction with the project results to create these resource maps:

- **Landings data**: Figures on UK landings by species are based on Marine and Fisheries Agency (MFA) data for 2009.\(^7\)
- **Import & export data**: Figures are derived from Seafish trade reports for 2009. These reports break down imports and exports by custom codes, which provide information on a species-specific basis. Custom codes can also provide some information on material format; for example, fillets, fish or processed meat.\(^8\)
- **Retail data**: Volumes of retail sales have been obtained from electronic point of sale (epos) information sourced by Nielsen on behalf of Seafish. These data help to identify major retail formats of fish on a species-specific basis.\(^9\)
- **Foodservice data**: Information on material passing through the foodservice sector is derived from work carried out by the NPD group to track the UK foodservice market. These data are based on consumer diaries of food eaten outside the home, and are presented on the basis of number of servings. Species-specific information is only available for a small number of species.\(^10\)
- **Value chain analysis**: Previous value chain studies carried out by Seafish provide valuable information on material flows through species supply chains. These studies have been carried out for cold water prawns, cod, haddock, nephrops and yellowfin tuna, and relevant data are included within these resource maps.\(^11,12,13\)

These data sources are summarised in Table 3.

### Table 3: Data sources used for resource maps

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>Source of data</th>
<th>OUTPUTS</th>
<th>Source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td><strong>Source of data</strong></td>
<td><strong>Type</strong></td>
<td><strong>Source of data</strong></td>
</tr>
<tr>
<td>Landings</td>
<td>Existing data</td>
<td>Retail products</td>
<td>Existing data</td>
</tr>
<tr>
<td>Imports</td>
<td>Existing data</td>
<td>Foodservice products</td>
<td>Existing data</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>Existing data</td>
<td>Processing wastes &amp;</td>
<td>Survey extrapolated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>co-products</td>
<td>estimate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retail wastes &amp; co-</td>
<td>Survey extrapolated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>products</td>
<td>estimate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exported products</td>
<td>Existing data</td>
</tr>
</tbody>
</table>

Additional, species-specific data sources are referenced on individual resource maps.

2.1.2 Estimates of wastes and co-products

**Processing**

A key aspect of these resource maps is a combined estimate of the volumes of waste and co-products derived from processing. This is extrapolated from figures provided by telephone survey and interview participants (see data extrapolation methodology in Appendix A). This approach generated figures for the average percentage waste and co-products quoted by different types of processor. These average figures were then applied to the total volume of raw material entering processing. This estimate of the total volume of material entering processing is derived on the following basis:

\[
\text{Raw material entering processing} = \text{Total supply chain inputs} - \text{direct exports}
\]

This accounts for the fact that, for some species, a significant proportion of material entering the supply chain undergoes minimal processing within the UK before being exported.
However, this figure assumes that all remaining material passes through processing rather than wholesale. For most species this is a reasonable assumption, as the quantity of material that passes through wholesale is relatively low.

Within the resource maps a combined figure is quoted for the total waste and co-products generated by processing operations. For many species it has not proved possible to break this figure down into sub-totals for co-products and wastes. Where a figure for the proportion of this material used as co-products is known, it is quoted in the resource map. Additionally, information on the most common methods of co-product utilisation, waste disposal or recovery for a species is commented on.

**Retail**

The resource maps contain an estimate of retail waste and co-products produced for each species. In all cases, these estimates are based on the following average figures obtained from discussions with the six multiples retailers who participated in this research:

- Fresh fish products: 5% waste arisings.
- Frozen and ambient fish products: 1% waste arisings.

It must be stressed that these figures incorporate products not sold at full retail price that are therefore considered a commercial waste to the retailer. A considerable amount of this material will later be sold via mark-down or via discount to staff. A variety of disposal or recovery methods may then be used for the remaining material. The derivation, and limitations, of these figures is discussed in more detail in Chapter 4: waste generation and minimisation within retail.

The figures used in our analysis are summarised in Table 4. It also highlights areas where estimated volumes cannot be derived and that have therefore been excluded from this study.

**Table 4: Factors included and excluded within resource maps and input: output charts**

| INPUTS                  |  | OUTPUTS                  |  |
|-------------------------|  |-------------------------|  |
| Edible inputs (included)|  | Products (included)     |  |
| Edible portions landed fish | Non-Edible portions landed fish | Retail products | Processing estimate (includes avoidable and unavoidable wastes and co-products) | Fishmongers: will include both avoidable and unavoidable wastes |
| Edible portions imports  | Non-Edible portions imports | Edible portion of exports | Non-edible portion of Exports (unavoidable) | Fish counter processing: unavoidable waste not included in retail estimates |
| Edible portions aquaculture | Non-Edible portions aquaculture | Foodservice products | Retail waste estimate (predominantly avoidable) | Non-edible portions which result in foodservice and consumer waste |

a) Estimates used where data available

**2.1.3 Resource map key**

The resource map structures show the main sources of inputs to and outputs from the UK supply chain, and highlight the quantities of waste and co-products generated at each key stage.

In the resource maps for finfish, the categorisations of ‘fish’ and ‘fillets’ are frequently used. This approach has been used to divide input and export materials into types of material:

- ‘Fillets’ = Any pre-processed material assumed to have 0% non-edible portion. This will include fillets, prepared or preserved fish or meat.
- ‘Fish’ = Any type of fish which contains a significant proportion of non-edible components. May include whole fish, gutted fish or headed and gutted fish (H&G).

Figure 2 presents a resource map glossary, explaining the information contained in the resource map structure.
Figure 2: Resource map glossary

**Inputs (volumes from landings\(^7\), imports\(^8\) or aquaculture)**

- **Overall Inputs**
  Total Figure including all inputs to supply chain (imports + landings + aquaculture)

- **Processing / Wholesale**
  Volumes of fish processed (or passing through wholesale) within the UK; excludes direct exports which undergo no UK processing

- **Retail X tpa**
  Retail volumes & proportions of fresh/frozen/ambient products\(^9\)

- **Wastes & Co-Products**
  Estimates of volumes produced at key stages of supply chain

- **Exports volumes**\(^8\)

- **Foodservice volumes**\(^10\)

- **Inputs / Outputs**
  (figures on volumes entering and leaving supply chain)

- **Notes**

---

**Input Formats:** Comments on format of materials entering UK supply chain and includes figures for edible and non-edible content. An understanding of input formats is essential to estimate the non-edible input to the supply chain, and therefore the quantity of unavoidable waste which is expected.

Non-edible input \(\approx X\) tpa

---

**Processing waste & co-product generation**

- Figures are based on survey data for processors carrying out specific operations; used to calculate the estimate shown

1) Comments on key issues which influence waste and co-products generation for this species

---

**Exports:** Value, type and estimated non-edible content of exports.

\(\approx X\) tpa exported non-edible material

---

**Retail waste & co-product generation**

1) Species-specific issues are highlighted including factors which may cause actual waste figure to differ from estimate given.

---

**Average processing co-product & waste levels:**

- Figures used for all species to calculate the species estimate shown.
  - 5% waste for fresh fish
  - 1% waste for frozen or ambient fish

- Limitations of these figures include the following:
  - Do not include processing waste (e.g. fish counter trimmings)
  - Includes products sold after markdown

---

Notes:

- 5% waste for fresh fish
- 1% waste for frozen or ambient fish
- Do not include processing waste (e.g. fish counter trimmings)
- Includes products sold after markdown

---

Material change for a better environment
2.1.4 Structure of input: output charts

These charts, which are presented for each species, provide an overview of inputs and outputs to the supply chain. The total volume of inputs combines the volumes for imports, landings and aquaculture quoted in the resource maps, and uses the estimates of format to break this overall input figure down into edible and non-edible components. Likewise, the total volume of products combines the resource map figures for retail products, foodservice products and an estimate of the edible portion of exports.

Finally, these charts incorporate an estimate for total supply chain waste and co-products, which are based on the estimates quoted in the resource maps and are derived according to the following formula.

**Total supply chain waste & co-products = Processing estimate + retail estimate + exported non-edible components**

This figure for the total supply chain can be compared to the expected figure for unavoidable arisings based on non-edible inputs. The intention was that this should enable an estimate for avoidable waste to be derived. Error margins have not been included within these total waste figures, as margins of error for both retail waste and non-edible exports cannot be calculated. However, it should be noted the estimates for processing include significant margins of error (as quoted in resource maps).

For species where there is a significant volume of exports, the output chart has been further broken down to clarify the quantity of products and wastes obtained within and outside the UK supply chain. These output breakdown bars highlight that for some species a significant amount of the non-edible portion will be exported, thereby reducing waste and co-product generation within the UK. Additionally, breakdowns of products to illustrate the relative proportions of retail and foodservice products have been included where species-specific data on foodservice is available.

In many instances, however, no species-specific data exists on foodservice, and estimates for these products have not been included. Where foodservice represents a substantial proportion of products, this has resulted in a significant imbalance between supply chain inputs and outputs. These estimated figures for total supply chain waste and co-products are likely to be lower than actual waste figures due to the excluded sources (Table 4). When figures for total waste and co-products are lower than estimates of unavoidable waste, this is likely to be influenced by the following factors which are not accounted for in our estimates:

- **Foodservice**: Products may include some non-edible content from seafood served whole or in shell.
- **Consumer**: Many final products will contain some non-edible content; for example shell, skin or bones.
- **Fishmongers**: Represents a relatively small proportion of retail (approx. 12% of market) but will produce some processing waste.
- **Fish counter processing**: Small amounts of processing are carried out by fish counters at multiple retailers. Waste generation from these sources is not included in retail estimates as no data was available.

**Input: output chart key**

The following colour coding system has been used to distinguish sections of these charts.

- **Blue**: Within inputs = Edible component. Within outputs = Product
- **Light Grey**: Within inputs = Non-edible component. Within outputs = Waste & Co-products

Where charts contain a breakdown of outputs, varying shades of blue are used to represent the different types of products, and varying shades of grey represent different categories of waste and co-products.

- **Dark Blue**: Foodservice products
- **Light Blue**: Retail products
- **Light Grey**: Exported edible
- **Medium Grey**: UK waste & co-products (includes processing & retail)
- **White**: Exported non-edible components
2.2 White fish resource maps

2.2.1 Key issues for white fish

The quantity of unavoidable waste and co-products arising within white fish supply chains will be highly influenced by factors such as the format of fish entering supply chains, the extent of pre-processing undertaken and the quantity of non-edible components the fish contains.

Table 5 shows the proportion of white fish species considered to be edible and non-edible in the UK. It is worth remembering that what is considered edible varies between countries and cultures. For example, there is a considerable market for export of dried fish heads to Africa. Another interesting example is monkfish cheeks, which are considered a delicacy in countries such as France, but in our analysis are included as non-edible content. It could therefore be surmised that by challenging our cultural perception of what is edible, the quantity of waste in UK supply chains could be reduced, albeit by only a small amount. This would however, require considerable effort to develop UK market demand for these materials. Furthermore, as noted in Table 5, extraction of cheeks is currently only commercially viable for larger fish. The volumes of cheek material which could be utilised even with increased market demand would therefore be expected to be low.

Table 5: Edible portions of white fish species

<table>
<thead>
<tr>
<th>Sector</th>
<th>Species</th>
<th>Edible portion (as proportion of landed / gutted weight)</th>
<th>Non edible portion (as proportion of landed / gutted weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Products / description</td>
<td>%</td>
</tr>
<tr>
<td>Whitefish</td>
<td>Cod, pollock, whiting</td>
<td>Fillet, Cod tongues &amp; cheeks¹</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Haddock</td>
<td>Fillet, Skin</td>
<td>40 - 42</td>
</tr>
<tr>
<td></td>
<td>Plaice</td>
<td>Fillet, Skin</td>
<td>35 - 52</td>
</tr>
<tr>
<td></td>
<td>Monkfish</td>
<td>Tail meat</td>
<td>30</td>
</tr>
</tbody>
</table>

¹ Cheeks are only commercially viable to recover from large fish

In addition to considering the edible proportions, it is important to understand the major supply chain inputs, processing stages and product types for each species of interest to this project. These factors are summarised in Table 6, and can all have a significant influence on the quantities of waste and co-products generated. Table 6 shows that, although processing operations and product types created are similar between species, there are noticeable differences in raw material formats. Consequently, considerable variation between unavoidable arisings in different white fish supply chains will result.
<table>
<thead>
<tr>
<th>Species</th>
<th>Formats entering UK supply chain\textsuperscript{a}</th>
<th>% total white fish\textsuperscript{b}</th>
<th>Major inputs to processors &amp; wholesalers</th>
<th>Major processing stages\textsuperscript{c}</th>
<th>Major products</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cod</td>
<td>75% ‘fillets’ 25% ‘fish’</td>
<td>37%</td>
<td>Whole</td>
<td>Filleting</td>
<td>Wide retail range</td>
<td>Processing waste will be proportionately low due to prevalence of pre-processed inputs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gutted</td>
<td>Skinning</td>
<td>Natural products</td>
<td>Significant exports</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fillets</td>
<td>Breading</td>
<td>Breaded or battered products</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Battering</td>
<td>Processed products including cakes and fish fingers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Other value added</td>
<td>Large volumes foodservice; &gt;90% fried fish</td>
<td></td>
</tr>
<tr>
<td>Haddock</td>
<td>35% ‘fillets’ 65% ‘fish’</td>
<td>32%</td>
<td>Whole</td>
<td>Filleting</td>
<td>Wide retail range</td>
<td>Processing waste will be proportionately high due to prevalence of ‘fish’ inputs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gutted</td>
<td>Skinning</td>
<td>Natural products</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fillets</td>
<td>Breading</td>
<td>Breaded or battered products</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Battering</td>
<td>Processed products including cakes and fish fingers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Other value added</td>
<td>Large volumes foodservice; &gt;80% fried fish</td>
<td></td>
</tr>
<tr>
<td>Monkfish</td>
<td>99% ‘fish’</td>
<td>6%</td>
<td>Gutted</td>
<td>Filleting</td>
<td>Limited retail sales, mainly as natural monkfish.</td>
<td>Processing waste high; all ‘fish’ inputs and high non-edible content</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Headed &amp; Gutted</td>
<td>No significant secondary processing</td>
<td>Foodservice significant route to market; high value restaurant products</td>
<td></td>
</tr>
<tr>
<td>Pollock</td>
<td>48% ‘fillets’ 52% ‘fish’</td>
<td>13%</td>
<td>Gutted</td>
<td>Filleting</td>
<td>Predominantly frozen retail products</td>
<td>Significant exports</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fillets</td>
<td>Skinning</td>
<td>Fish fingers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fish Blocks</td>
<td>Breading</td>
<td>Breaded or battered products</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Battering</td>
<td>No foodservice data; assume significant volumes of fried fish</td>
<td></td>
</tr>
<tr>
<td>Plaice</td>
<td>39% ‘fillets’ 61% ‘fish’</td>
<td>8%</td>
<td>Whole</td>
<td>Filleting</td>
<td>Retail: breaded and natural products</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gutted</td>
<td>Skinning</td>
<td>No figures on foodservice volumes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fillets</td>
<td>Breading</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whiting</td>
<td>100% ‘fish’</td>
<td>4%</td>
<td>Whole</td>
<td>Filleting</td>
<td>Limited retail sales, mainly as natural whiting, some breaded</td>
<td>Processing waste proportionately high due to ‘fish’ inputs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gutted</td>
<td>Skinning</td>
<td>No figures on foodservice volumes</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a} ‘Fillets’ include other pre-processed imports such as prepared fish or meat. ‘Fish’ include whole, gutted or headed and gutted fish. Exact formats of fish cannot be clarified for either imports or landings.

\textsuperscript{b} Per cent of total volumes of white fish based on six species of interest to this project.

\textsuperscript{c} Focus on stages where waste generation expected to occur. Additional operations such as chilling, freezing and thawing are common to all white fish species.
2.2.2 White fish estimates of waste and co-products

The resource maps include an extrapolated estimate for processing waste and co-products, derived from average figures for companies participating in the project. Filleting generates the highest quantity of waste and co-products in white fish operations; however, this predominantly consists of non-edible fish components and is unavoidable. Participating white fish processors have therefore been subdivided into ‘filleting’ and ‘non-filletting’ processors, and a separate estimate of average waste and co-products obtained for the two categories.

The accuracy of these estimates is limited by several factors:

- Figures for ‘average % processing waste and co-products’ are derived across all white fish. Some species-specific variations will therefore be lost.
- The extrapolated processing estimates are based on figures for supply chain inputs from other sources (landings and imports). The margins of error in these figures are not known.
- Data on export volumes and formats have been used to estimate a volume for ‘direct exports’. This is material considered to be exported without undergoing any processing in the UK.
- The estimate for processing assumes that all inputs, except for direct exports, pass through processing rather than wholesale. This, in principle, should result in an overestimate of processing waste and co-products; however, where white fish wholesale volumes are known, they are relatively low (5% for cod and 12% for haddock) so the error should be relatively trivial.
- Estimates for wholesale are not specifically included; however, once again the relatively modest wholesale volumes make this a negligible error.
- Quantities of exported non-edible portions are based on assumptions about the format of exported fish.

The quantity of non-edible material inputs can be treated as an estimate of the unavoidable waste and co-products, which would be expected to occur within supply chains. Filleting also results in some possibly avoidable wastes, comprising edible material which is not currently commercially viable to remove. However, it is believed that waste of this type is extremely minimal, as filleting is highly effective in removing maximum yield from the fish.

2.2.3 Cod

Figure 3 summarises the overall breakdown of inputs and outputs to the cod resource map. This illustrates the relative proportions of edible and non-edible components entering the supply chain, and quantities of products and wastes and co-products derived.

The resource map for cod, Figure 4, provides estimates of waste and co-product generation within processing and retail, as well as highlighting issues that contribute to these figures.

Within white fish processing, the majority of non-edible material is a valuable co-product sold by processors to fishmeal plants, for conversion to fish oil and fish meal for use as aquaculture feed. For white fish, a figure of 77% utilisation of co-products in fishmeal has been derived from our results (for further discussion see Chapter 3, processing and wholesale wastes and co-products), and this figure is used in the resource maps. Disposal of fish waste from this sector is consequently considered to be low.

The following points are noted:

- Cod is a highly significant and high volume species within the UK market.
- The proportion of non-edible inputs is relatively low due to the dominance of pre-processed imports in the inputs.
- The cod supply chain is complicated and incorporates a wide range of processing operations.
- The majority of the unavoidable waste resulting from non-edible components will be manifest outside the UK due to export of ‘fish’ products.
- Cod processing wastes and co-products are low based on the relatively low amount of domestic filleting being done (since there is a large proportion of pre-processed imports).
- Although an average retail waste figure of 5% has been used in the resource map, cod retail waste may in reality be lower. One retailer quoted a figure of 1% waste for high volume, stable demand species such as cod.
Figure 3 shows a good correlation between the quantity of edible fish entering the UK market and the quantity of products derived, indicating that the quantity of avoidable waste generated by the UK supply chain is low. The estimate of total waste is heavily influenced by the high proportions of exported non-edible components, and may be subject to a significant level of error due to assumptions on export format.

**Figure 3: Summary of inputs and outputs to cod supply chain**

<table>
<thead>
<tr>
<th>Inputs (tpa)</th>
<th>Edible 104,800</th>
<th>Non-Edible 16,400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputs (tpa)</td>
<td>Products 105,300</td>
<td>Waste &amp; co-products 17,700</td>
</tr>
<tr>
<td>Outputs breakdown (tpa)</td>
<td>Foodservice 45,000</td>
<td>Exported Edible 21,100</td>
</tr>
</tbody>
</table>
Figure 4: Cod resource map

Inputs / Outputs

- Landings 13,900tpa
- Imports 107,300tpa
- Exports 33,700tpa
- Foodservice 45,000tpa

Overall Inputs

- 121,200tpa

Processing / Wholesale

- 94,150tpa / 4,950tpa
  (Excludes direct exports)
- Wide range of primary and secondary processing operations

Processing waste & co-product generation

1) Filleting produces high volume of non-edible by-products but most cod filleted before entering UK.
2) Secondary processing will generate breadcrumb and batter waste.
3) Majority of this material (approx 77%) is considered a valuable co-product and sold to fishmeal plants.

Retail

- 40,900tpa
  - 21% fresh, 79% frozen

Retail waste & co-product generation

1) Cod is a high volume retail product so lower waste levels than other species may be expected; real value may therefore be lower than estimate.
2) High volumes of frozen products result in a relatively low volume of cod waste from retail.

Wastes & Co-Products

- Gutting at sea (unknown)

Overall

- 121,200tpa

Exports

- £75m, 73% "fish" (51% inedible), 27% "fillets"
  ≈ 12,500tpa exported non-edible material

Imports

- 85% “fillets” / 15% “fish” (£351.8m)

Landings: primarily gutted fish (£23.7m)

Average processing co-product & waste levels for white fish: filleting processors 35%, non-filleting processors 3%.

Notes

- Non-edible input ≈ 16,400tpa
- Landings: primarily gutted fish (£23.7m)
- Imports: 85% “fillets” / 15% “fish” (£351.8m)
- Overall: 75% of inputs “fillets” (all edible), 25% “fish” with non-edible content (whole fish 64%, gutted 58%, headed and gutted 43%).
2.2.4 Haddock

Figure 5 summarises the overall breakdown of inputs and outputs to the haddock resource map. This illustrates the relative proportions of edible and non-edible components entering the supply chain, and quantities of products, co-products and wastes derived.

The resource map for haddock, Figure 6, provides estimates of waste and co-product generation in processing and retail, as well as highlighting issues which contribute to these figures.

As in the case of cod, the majority of haddock by-products from UK processing will be sent to fishmeal plants where they constitute a valuable co-product.

The following points are noted:

- Haddock is a highly significant, high volume species within the UK market.
- The proportion of non-edible inputs is relatively high due to the dominance of whole landed fish inputs.
- The extrapolated estimate of total waste and co-products is considerably lower than would be expected from the non-edible inputs.
- Known quantities of UK haddock products are considerably lower than inputs would indicate.
- Haddock exports are relatively low so the breakdown of UK and exported wastes and co-products has not been included in Figure 5.
- Although the average retail waste figure of 5% has been used in the resource map, haddock retail waste may in reality be lower. One retailer quoted a figure of 1% waste for high volume, stable demand species such as haddock.

The discrepancy in Figure 5 between inputs and outputs may be due to several factors. Estimates of processing waste and co-products are based on an average for all white fish types. A higher percentage than this may, in reality, be applicable to haddock due to the higher proportion of unprocessed fish entering the supply chain.

The quantity of UK products may also be inaccurate. For example, the foodservice estimate is derived from a 2003 study which may now be out of date. More recent data on foodservice indicates an increase in fish and chip shop sales which may account for some additional haddock products. Unfortunately, this data is only available as a number of servings and is not species-specific, so cannot be incorporated quantitatively in our model.

Figure 5: Summary of inputs and outputs to haddock supply chain
**Figure 6: Haddock resource map**

**Inputs / Outputs**
- **Landings** 35,500tpa
- **Imports** 68,100tpa
- **Exports** 3,000tpa
- **Foodservice** 22,400tpa

**Processing / Wholesale**
- **Overall Inputs** 103,600tpa
- **Processing / Wholesale** 91,200tpa / 12,400tpa
  - (Excludes direct exports)
  - Wide range of primary and secondary processing operations

**Wastes & Co-Products**
- **Overall Inputs** 103,600tpa
- **Processing / Wholesale** 23,900 ±2,000tpa
- **Retail** 23,600tpa
  - 41% fresh, 59% frozen
- **Exports**
  - £7.2m, 47% "fish" (51% inedible), 53% "fillets" ≈ 700tpa exported non-edible material

**Notes**
- **Landings**: primarily gutted fish (£35.5m)
- **Imports**: 47% "fillets" / 53% "fish" (£162.7m)
- **Overall**: 35% of inputs "fillets" (all edible), 65% "fish" with non-edible content (whole fish 64%, gutted 58%, headed and gutted 43%)
  - Non-edible input ≈ 37,300tpa
- **Average processing co-product & waste levels for white fish**: Filleting processors 35%, non-filleting processors 3%.
- **Processing waste & co-product generation**
  - Filleting most significant cause of waste; large volumes of haddock filleted within UK.
  - Secondary processing will generate breadcrumb and batter waste.
  - Majority of this material (approx 77%) is considered a valuable co-product and sold to fishmeal plants.
- **Retail waste & co-product generation**
  - 1) Haddock is a high volume retail product so lower waste levels than other species may be expected; real value may therefore be lower than estimate.
2.2.5 Monkfish

Figure 7 summarises the overall breakdown of inputs and outputs to the monkfish resource map. This illustrates the relative proportions of edible and non-edible components entering the supply chain, and quantities of products and wastes and co-products derived.

The resource map for monkfish, Figure 8, provides estimates of waste and co-product generation in processing and retail, as well as highlighting issues that contribute to this figure.

The following points are noted:

- The proportion of non-edible inputs is relatively high due to the dominance of whole landed monkfish.
- The non-edible portion of the monkfish is particularly high due to the fish’s large head (see illustration).
- Monkfish processing consists mainly of primary operations.
- A significant proportion of non-edible components will be manifest outside the UK due to the export of ‘fish’ products.
- No data exists for monkfish products in the foodservice sector. However, it is assumed that these will account for the majority of UK products.
- The high value, low volumes and prevalence of fresh products may result in proportionately higher retail waste for monkfish. An average figure of 5% has been used in the resource map, but in reality a higher value may apply.

The discrepancy between non-edible inputs, and the total figure estimated for supply chain waste and co-products, is probably accounted for by there being a different percentage of filleting waste arising from monkfish compared to other species. The figure of 35% waste for all white fish filleters was used in our calculations; however, in reality, the high non-edible portion of monkfish will result in a higher proportion of wastes during filleting. Our figure is therefore likely to be an underestimate.

Figure 7: Summary of inputs and outputs to monkfish supply chain (not including foodservice estimate)
Figure 8: Monkfish resource map

**Inputs / Outputs**
- Landings: 15,300tpa
- Imports: 2,800tpa
- Exports: 4,100tpa
- Foodservice: no data

**Processing 14,200tpa**
(Excludes direct exports)
Predominantly primary processing operations

**Overall Inputs**
18,000tpa

**Processing waste & co-product generation**
1) Filleting most significant cause of waste; most monkfish inputs filleted within UK.
2) Monkfish filleting produces higher volumes of non-edible material than other white fish (due to large head).
3) Majority of this material (approx 77%) is a valuable co-product sold to fishmeal plants.

**Exports**:
- £31.8m, 90% “fish” (65% non-edible), 10% “fillets” ≈ 2,700tpa exported non-edible material

**Retail waste & co-product generation**
1) Monkfish is a low volume, high value retail product and higher waste levels than other species may be expected; real value may be higher than estimate.
2) High proportion of fresh products will result in high waste levels in relation to volumes of sales.

**Notes**
- Landings: primarily gutted fish (£41.9m)
- Imports: 93% “fish” (£9.6m)
- Overall: >99% “fish” with non-edible content (gutted 70%, headed and gutted 20%)
  Non-edible proportion of monkfish higher than other white fish
  Non-edible input ≈ 11,100tpa
- Average processing co-product & waste levels for white fish: filleting processors 35%, non-filletting processors 3%.
- Gutting at sea (unknown)

**Wastes & Co-Products**
- Overall Inputs
- Processing 14,200tpa
- Retail 100tpa
- Consumer

**Overall Inputs**
18,000tpa

**Exports**
4,100tpa (Excludes direct exports)

**Retail 100tpa**
93% fresh

**Consumer**

**Non-edible proportion** of monkfish higher than other white fish

**Non-edible input** ≈ 11,100tpa

- Non-edible proportion of monkfish higher than other white fish
- No non-edible input ≈ 11,100tpa

**Processing waste & co-product generation**
- Filleting most significant cause of waste; most monkfish inputs filleted within UK.
- Monkfish filleting produces higher volumes of non-edible material than other white fish (due to large head).
- Majority of this material (approx 77%) is a valuable co-product sold to fishmeal plants.
2.2.6 Pollock

Figure 9 summarises the overall breakdown of inputs and outputs to the pollock resource map. This illustrates the relative proportions of edible and non-edible components entering the supply chain, and quantities of products and wastes and co-products derived.

The resource map for pollock, Figure 10, provides estimates of waste and co-product generation within processing and retail as well as highlighting issues which contribute to these figures.

The following points are noted:

- The proportion of non-edible inputs is relatively low due to the high volume of pre-processed imports in the input stream.
- No data exists for foodservice products. It is believed that these are significant and would therefore account for much of the discrepancy seen between edible inputs and product outputs.
- Considerable secondary processing of pollock takes place; for example breading, battering and production of fish fingers.

The majority of pollock retail products are frozen so retail waste is low.

**Figure 9**: Summary of inputs and outputs to pollock supply chain (not including foodservice estimate)
Figure 10: Pollock resource map

Inputs / Outputs

- Landings: 21,300tpa
- Imports: 22,700tpa
- Exports: 3,500tpa
- Foodservice: no data

Overall Inputs: 44,000tpa

Processing 41,800tpa (Excludes direct exports)
- Pollock has a high level of secondary processing

- Gutting at sea (unknown)
- Processing waste & co-products: 7,500 ±700tpa

Retail 16,600tpa
- 94% frozen

Notes:

Landings: primarily gutted fish (£17.4m)
Imports: 94% "fillets" (£47.1m)
Overall: 48% "fillets" (all edible) 52% "fish" with non-edible content (gutted 58%, headed and gutted 43%)

Non-edible input ≈13,100tpa

Average processing co-product & waste levels for white fish:
- Filleting processors 35%, non-filleting processors 3%

Processing waste & co-product generation:
1) Filleting most significant cause of waste.
2) Majority of this material (approx 77%) is a valuable co-product sold to fishmeal plants.
3) Secondary processing will generate breadcrumb and batter waste.

Exports: £7.8m, 65% "fish" (51% non-edible), 35% "fillets" ≈1,200tpa exported non-edible material

Retail waste & co-product generation:
1) Majority of Pollock products are frozen; this leads to low waste arisings relative to sales volumes.
2.2.7 Plaice

Figure 11 summarises the overall breakdown of inputs and outputs to the plaice supply chain. The same data has been used to create the plaice resource map, Figure 12, which provides estimates of waste and co-product generation within processing and retail, as well as highlighting issues which contribute to these outputs.

The following points are noted:

- The lack of correspondence between edible inputs and identified products can be at least partially attributed to the lack of an estimate on foodservice quantities.
- The estimate of waste and co-products is significantly lower than expected from the non-edible portion of inputs.

The discrepancy between estimated waste and co-product quantities and non-edible inputs may be due to a number of factors. Inaccuracies in the estimate of non-edible inputs may arise from a lack of robust data on import formats. Additionally the estimate for processing may not reflect some species-specific issues for plaice. For example, the non-edible content of plaice is approximately 50% but this can vary from 48 to 65% depending on the size of the plaice and the season, both of which have an effect on yield.

Figure 11: Summary of inputs and outputs to plaice supply chain (not including foodservice estimate)
Figure 12: Resource map for plaice

**Inputs / Outputs**
- **Landings**: 3,400 tpa
- **Imports**: 24,300 tpa
- **Exports**: 1,700 tpa
- **Foodservice**: No data

**Overall Inputs**: 27,700 tpa

**Processing 26,200 tpa** (Excludes direct exports)
- Operations include primary and secondary processing
- **Processing waste & co-products generation**:
  1) Filleting most significant cause of waste.
  2) Majority of this material (approx. 77%) is a valuable co-product sold to fishmeal plants.
  3) Secondary processing will generate breadcrumb and batter waste.
- **Exports**: £2.9m, 90% "fish" (51% non-edible), 10% "fillets"
- **Non-Edible input**: ≈ 9,400 tpa

**Retail 3,000 tpa**
- 65% fresh, 35% frozen
- **Retail waste & co-product generation**:
  1) Majority of plaice products are fresh; this leads to a high value of waste arising relative to sales volumes.

**Wastes & Co-Products**
- Gutting at sea (unknown)
- **Landings**: primarily gutted fish (£17.4m)
- **Imports**: 44% "fillets"/56% "fish" (£47.1m)
- **Overall**: 39% "fillets" (all edible) 61% "fish" with non-edible content (gutted 58%, headed and gutted 43%)
- **Non-Edible input**: ≈ 9,400 tpa

**Notes**
- Average processing co-product & waste levels for white fish: Filleting processors 35%, non-filleting processors 3%.
- **Exports**: £2.9m, 90% "fish" (51% non-edible), 10% "fillets"
- **Non-Edible input**: ≈ 9,400 tpa

**Consumer**
2.2.8 Whiting

Figure 13 summarises the overall breakdown of inputs and outputs to the whiting resource map, which is presented in Figure 14.

The following points are noted:

- The proportion of non-edible inputs is relatively high due to the dominance of whole landed fish in the input stream.
- The lack of foodservice data will contribute to the lack of correspondence between edible inputs and product outputs.
- No data exists on whiting exports.

As noted for other species, the estimate of waste is noticeably lower than the quantity of unavoidable waste projected from non-edible inputs. The lack of data on exports may contribute to this. Additionally, as the processing waste estimation is based on data for all white fish, this may not be accurate for this particular species, which has a processing yield of approximately 44%. However, processing yields do vary significantly for finfish species, depending on size and season.

**Figure 13**: Summary of inputs and outputs to whiting supply chain (not including foodservice estimate)
Figure 14: Resource map for whiting

Inputs / Outputs

- **Landings**: 11,800tpa

Wastes & Co-Products

- **Overall Inputs**: 11,800tpa
  - **Processing**: 11,800tpa
    - Assumes no direct exports
    - Filleting processors 35%, non-filleting processors 3%
    - Filleting most significant cause of waste; all whiting inputs assumed to be filleted within UK.
    - Majority of this material (approx 77%) is a valuable co-product sold to fishmeal plants.
- **Retail**: 200tpa
  - 70% fresh, 30% frozen
  - **Retail waste & co-product generation**
    - Whiting is a low volume retail product which may result in higher waste arisings than other species; real value may be higher than estimate.
- **Consumer**
- **Exports**: no data
- **Foodservice**: no data

Notes

- **Landings**: primarily gutted fish (£35.5m)
- **Overall**: All is "fish" with non-edible content (whole fish 64%, gutted 58%)
- **Non-edible input** ≈ 7,000tpa

Average processing co-product & waste levels for white fish:

- Filleting processors 35%, non-filleting processors 3%.

Processing waste & co-product generation

1) Filleting most significant cause of waste; all whiting inputs assumed to be filleted within UK.
2) Majority of this material (approx 77%) is a valuable co-product sold to fishmeal plants.

Retail waste & co-product generation

1) Whiting is a low volume retail product which may result in higher waste arisings than other species; real value may be higher than estimate.
2.2.9 All white fish

The resource maps above show a lack of correlation between edible input and product outputs in several cases. We suspect that a lack of specific foodservice data for some species accounts for much of this. Foodservice data from CREST provides a figure of 219m servings of white fish categorised as other or unknown. Based upon reasonable portion sizes, we estimate that this equates to approximately 69,000tpa, which may be any of the six white fish species included in this study.

To illustrate this, this figure has been incorporated into the overall white fish mass balance shown in Figure 15, increasing the size of the foodservice bar in the output breakdown.

Figure 15: Summary of inputs and outputs to all white fish supply chains (includes foodservice products).

Such analysis shows reasonably good agreement between the volume of edible fish entering supply chains, and the quantity of products reaching the market in retail, foodservice and via export. The higher volume of products than edible inputs may be reasonably attributed to product weight increases resulting from breading or battering. Some of these products may also contain a small amount of non-edible components; for example, whole fish or fillets with skin.

As highlighted in Table 4, the estimate of total waste in Figure 15 does not include all sources of waste, e.g. it does not include waste from fishmongers. Non-edible material which ends up with consumers is also excluded. These factors account, at least in part, for the difference between the estimated 70,000tpa of waste and co-products and the expected figure based on 94,400tpa of non-edible inputs. The margin of error for non-edible input is unknown, and we have made several assumptions on format to derive this figure. Similarly, the margin of error on the waste and co-product estimate is known to be significant (see figures included in resource maps), and may contribute to the discrepancy seen.

In conjunction with the general agreement between the amount of edible material entering the supply chain and volumes of products, the low estimate of total waste and co-products indicates that generation of avoidable waste in the white fish supply chain is relatively low. Given the known and probable margins of error, it is not possible to derive an estimate of this figure with any confidence.

Further comments on the causes, treatment and minimisation of waste may be found in Chapter 3 (processing waste and co-products) and Chapter 4 (retail waste).
2.2.10 Summary of white fish

Resource mapping of the white fish supply chain allows us to conclude that:

- Of the total estimate of 70,000tpa of waste and co-product arisings: 72% is from processing, 2% is from retail and 26% is non-edible portions of exports.
- Of the 52,100tpa of processing waste and co-product arisings, it is estimated that 77% is utilised in fishmeal production (≈40,000tpa) and constitutes an additional source of income for white fish processors.
- High volumes of non-edible inputs result in high waste and co-product arisings within processing.
- The biggest source of processing waste and co-products is unavoidable material from filleting operations.
- Within the margins of error of our estimates, it is not possible to estimate quantities of avoidable waste within white fish processing. However, the results are consistent with minimal generation of avoidable waste in processing operations.
- Retail waste will predominantly be avoidable and is a very small contributor to total waste.
2.3 Pelagic resource maps

Pelagic fish include oily species such as mackerel, herring and tuna. This section includes a summary of processing yields and the supply chain structure for pelagic fish as well as detailed resource maps showing the estimated quantities of edible products, processing waste and co-products generated within each pelagic supply chain.

2.3.1 Key issues for pelagic fish

Mackerel and herring are typically landed as whole fish, whereas tuna is largely imported as a semi-processed product. As for white fish, the quantity of wastes and co-products generated within pelagic supply chains will be strongly influenced by the quantities of non-edible inputs. Table 7 shows the proportions of pelagic fish considered to be edible and non-edible within the UK.

Table 7: Edible portions of pelagic fish

<table>
<thead>
<tr>
<th>Sector</th>
<th>Species</th>
<th>Edible portion (as proportion of landed / gutted weight)</th>
<th>Non edible portion (as proportion of landed / gutted weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelagic</td>
<td>Mackerel and herring</td>
<td>Fillet 53</td>
<td>Frame (skeleton), head, belly flaps/lining, fins, viscera</td>
</tr>
<tr>
<td>Tuna</td>
<td>Bullets / tail meat</td>
<td>42</td>
<td>Frame (skeleton), head, viscera</td>
</tr>
</tbody>
</table>

a) Viscera from fish landed whole

In addition to considering the edible inputs, it is important to understand the major supply chain inputs, processing stages and product types for each species. These factors are summarised in Table 8, and will have a significant influence on the quantity of waste generated. This table highlights that herring and mackerel have very similar supply chains. Both are sourced predominantly from UK landing and, as processing at sea is minimal, enter UK processing with a high proportion of non-edible content. By contrast, tuna undergoes considerable processing in its country of origin, and imports comprise predominantly edible components. Levels of processing waste reflect these differences in inputs, with mackerel and herring giving rise to much higher UK waste arisings than tuna.

Table 8: Summary of supply chain structure for pelagic fish

<table>
<thead>
<tr>
<th>Species</th>
<th>Formats entering UK supply chain</th>
<th>Major Inputs to processors &amp; wholesalers</th>
<th>Major Processing Stages</th>
<th>Major products</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herring</td>
<td>96% 'fish' 4% 'fillets'</td>
<td>Whole fish (UK landed)</td>
<td>Filleting</td>
<td>Limited UK retail &amp; predominately natural products</td>
<td>High proportion of non-edible inputs; large volume of herring exports predominantly as 'fish'</td>
</tr>
<tr>
<td>Mackerel</td>
<td>97% 'fish' 3% 'fillets'</td>
<td>Whole fish (UK landed)</td>
<td>Filleting, Gutting, Smoking</td>
<td>High volume retail &amp; smoked products</td>
<td>High proportion of non-edible inputs; large volume of mackerel exports; predominantly as 'fish'</td>
</tr>
<tr>
<td>Tuna</td>
<td>93% prepared or preserved 7% fresh or frozen</td>
<td>Loins Bullets</td>
<td>Cut to size, Repackaging</td>
<td>High volume retail &amp; foodservice; 97% retail sales are canned fish</td>
<td>Predominantly pre-processed inputs with low non-edible portion; V limited UK processing</td>
</tr>
</tbody>
</table>

a) 'Fillets' include other pre-processed imports such as prepared fish or meat. 'Fish' include whole, gutted or headed and gutted fish. Exact formats of fish cannot be clarified for either imports or landings.
b) Focus on stages where waste generation expected to occur. Additional operations such as chilling, freezing and thawing are common to all species.
2.3.2 Estimates of processing waste and co-products

The resource maps for herring and mackerel include an extrapolated estimate for processing waste and co-products, derived from average figures for companies participating in the project. Filleting makes the largest contribution to this figure; however, this material is predominantly unavoidable, consisting of non-edible fish components. Participating processors have therefore been subdivided into 'filleting' and 'non-filleting' processors, and a separate estimate of average waste and co-products obtained for the two categories.

The accuracy of these estimates is limited by several factors:

- Figures for 'average % processing waste and co-products' are derived across both species. Some species-specific variations will therefore be lost.
- The extrapolated processing estimates are based on figures for supply chain inputs from other sources (landings and imports). The margins of error in these figures are not known.
- Data on export volumes and formats have been used to estimate a volume for 'direct exports'. This is material which is considered to be exported without undergoing any processing in the UK.
- The derivation of a figure for processing waste and co-products assumes that all inputs pass through processing rather than wholesale. This may therefore result in an overestimate.
- Estimates of wholesale waste are not specifically included. However, as noted above, this should be overcompensated for by the assumption that all material passes through processing.
- Quantities of exported non-edible portions are based on assumptions about the format of exported fish.

The quantity of non-edible material inputs can be treated as an estimate of the unavoidable waste and co-products that would be expected to occur within supply chains.

Additional outputs will include possibly avoidable waste from edible material, which is not commercially viable to remove. However, it is believed that this is extremely minimal, as filleting is highly effective in maximising edible yield from the fish.

Tuna differs considerably from the other two pelagic fish, and, due to insufficient survey data, it has not been possible to derive an estimate of processing waste from the current data set. Previous information has therefore been used to produce an estimate.

2.3.3 Herring

Figure 16 summarises the overall breakdown of inputs and outputs to the herring supply chain. This illustrates the relative proportions of edible and non-edible components entering the supply chain and quantities of outputs derived. The resource map for herring, Figure 17, provides estimates of waste and co-product generation within processing and retail, and highlights issues which contribute to this figure.

Within pelagic processing, the vast majority of non-edible material obtained is exploited as a valuable co-product, and sold by processors to fishmeal plants for conversion to fish oil and fish meal for use as aquaculture feed. A figure of 95% co-product utilisation has been used in the resource maps for herring and mackerel (see Section 3.3.2).

The following points are noted:

- Herring predominantly enters UK processing as whole fish.
- The majority of herring entering the UK is exported with minimal processing.
- The majority of the non-edible components will be manifest outside the UK due to export of ‘fish’ products.
- The quantity of herring processing waste and co-products derived within the UK are consequently relatively low.
- No data exists for herring foodservice, and this will account for a small volume of additional products.

Both the estimate of total waste and co-products, and the quantity of products shown in Figure 16, are heavily influenced by the high proportion of herring exports. Information from customs codes has been used to...
estimate the relative proportion of edible and non-edible material within these exports. However, these figures may be subject to a significant margin of error.

Consequently, although Figure 16 shows reasonable correlation between edible inputs and products, it is not possible to infer that this is indicative of low avoidable waste arisings. The overall discrepancy between the volume of inputs and outputs indicates that our model does not accurately reflect all material flows within this supply chain.

**Figure 16:** Summary of inputs and outputs to herring supply chain
Figure 17: Resource map for herring

**Inputs / Outputs**
- Landings 41,900tpa
- Imports 8,500tpa
- Exports 34,300tpa
- Foodservice no data

**Processing 24,000tpa** (excludes direct exports)
Wide range of primary and secondary processing operations

**Overall Inputs** 50,400tpa

**Retail 1,400tpa**
74% fresh, 26% frozen

**Notes**

- **Landings:** primarily whole fish (£12.8m)
- **Imports:** 47% "fillets" / 53% "fish" (£11.0m)
- **Overall:** 6% of inputs "fillets" (all edible); 94% "fish" assumed whole fish with non-edible content 47%.

**Non-edible input ≈22,300tpa**

**Processing waste & co-product generation**
1) Filleting most significant cause of waste but significant quantities of herring are exported without processing.
2) Majority of this material (approx 95%) is a valuable co-product sold to fishmeal plants.

**Exports:** £18.3m, 77% "fish" (47% non-edible), 23% "fillets" ≈ 11,600tpa exported non-edible material

**Retail waste & co-product generation**
1) Herring is a low volume retail product which may result in relatively high waste arisings; real value may be higher than estimate.
2.3.4 Mackerel

The input: output chart, Figure 18, and resource map, Figure 19, summarise the inputs and outputs to the mackerel supply chain, and highlight the issues which contribute to waste and co-product generation.

As in the case of herring, the majority of mackerel co-products from UK processing (estimated at 95%) will be sent to fishmeal sites where it is used to generate valuable secondary products.

The following points are noted:

- Very high volumes of mackerel enter UK supply chains.
- The majority of this mackerel is exported with minimal processing; however, there is still a strong UK processing sector for this species.
- Mackerel predominantly enters UK processing as whole fish; filleting therefore results in production of non-edible by-products.
- Mackerel represents considerable volumes of retail and foodservice sales within UK markets.
- The majority of non-edible components will be manifest outside the UK due to export of ‘fish’ products.

Mackerel and herring supply chains shows considerable similarities in that exports make up the majority of outputs. The breakdown of outputs shown in Figure 18 is therefore strongly influenced by assumptions made on the format of exports. As noted for herring, the estimates of edible and non-edible content in these exports may be subject to a considerable margin of error.

Based on the assumptions made on format, reasonable correlation is seen between the volume of edible inputs and product outputs. There is, however, a notable difference between the total volume of inputs and outputs indicating that, in this instance, a considerable amount of material is not accounted for by our model. As noted above, assumptions made on export format may be a significant factor in this.

**Figure 18:** Summary of inputs and outputs to mackerel supply chain
Figure 19: Resource map for mackerel

Inputs / Outputs

<table>
<thead>
<tr>
<th>Landings</th>
<th>121,800tpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imports</td>
<td>32,300tpa</td>
</tr>
</tbody>
</table>

Processing 55,100tpa (excludes direct exports)
Wide range of primary and secondary processing operations

Overall Inputs 154,100tpa

Wastes & Co-Products

Gutting at sea (unknown)

Notes

Landings: primarily whole fish (£173.1m)
Imports: 15% "fillets" / 85% "fish" (£44.5m)
Overall: 3% of inputs "fillets" (all edible); 97% "fish" assumed whole fish with non-edible content 47%.

Non-edible input ≈70,300tpa

Average processing co-product & waste levels for pelagic fish:
filleting processors 23%, non-filleting processors 10%.

Processing waste & co-product generation

1) Majority of mackerel products are fresh; this leads to a high value of waste arising relative to sales volumes.
2) Filleting most significant cause of waste but significant quantities of mackerel are exported without processing.
3) Majority of this material (approx 95%) is a valuable co-product sold to fishmeal plants.
4) Exported non-edible material

Exports: £121.1m, 96% "fish" (47% non-edible), 4% "fillets" ≈ 43,500tpa exported non-edible material

Retail 15,500tpa
67% fresh, 33% frozen

Retail waste & co-product generation

Exports: 103,100tpa
2.3.5 Tuna

The input: output chart, Figure 20, and resource map, Figure 21, summarise the inputs and outputs to the tuna supply chain and highlight the issues which contribute to waste and co-product generation.

The tuna supply chain and resource map are very different to those of herring and mackerel discussed above. Tuna is solely sourced from imports and the majority of this material is pre-processed in the country of origin. The most common format for tuna entering the UK is as prepared or preserved products, predominantly canned tuna. Fresh and frozen tuna imports are also predominantly pre-processed, and enter the UK either as fillets or loins. Very minimal processing of tuna is carried out within the UK, consisting mainly of thawing, chilling, repackaging and cutting to size.

The following points are noted:

- Quantities of non-edible material entering the UK supply chain are minimal.
- Very low waste arisings occur in processing and wholesale.
- Retail waste arisings are low as the majority of products are long shelf-life ambient products.

Although it cannot be quantified within the resource map, it is likely that waste arisings for fresh tuna products within retail may be higher than average. Fresh tuna is a high value and relatively low volume product, generally associated with higher waste levels. One multiple retailer respondent also commented that browning of tuna can lead to product being rejected by consumers while it is still in date.

The wide variety of tuna species and formats makes it difficult to obtain a complete figure on the volume of tuna imports entering the UK. The difference seen between the quantity of edible inputs and product outputs seen in Figure 20 may therefore be due to inaccuracy in the figure for import volumes.

Although the processing waste estimate quoted in the resource map is derived from a previous study, data acquired within our survey supports this figure. These figures are consistent with both unavoidable and avoidable wastes within UK tuna processing being minimal. It must, however, be recognised that this low UK figure is the result of processing waste being created elsewhere in a global supply chain.

Figure 20: Summary of inputs and outputs to tuna supply chain
Figure 21: Resource map for tuna

**Imports**
124,000tpa

**Foodservice**
35,000tpa ambient
1,300tpa fresh

**Overall Inputs**
124,000tpa

**Processing/Wholesale**
6,200tpa/2,500tpa
(Excludes prepared and preserved products)
Minimal processing of tuna takes place within UK

**Retail**
74,800tpa
>96% ambient, 3% fresh

**Consumer**

**Imports**
£283m.
93% prepared or preserved (i.e. canned)
7% fresh or frozen; predominantly fillets and loins (assume 4% non-edible)

**Non-edible input ≈ 300tpa**

**Processing waste & co-product generation**
1) No filleting of tuna takes place in UK.
2) Processing comprises repackage and cut to size i.e. low waste operations.
3) Insufficient survey data obtained to estimate processing waste
4) 3% figure of tuna processing and wholesale waste from previous study used.

**Retail waste & co-product generation**
1) Overall tuna has relatively low waste arisings due to prevalence of long shelf-life ambient products.
2) Waste levels for fresh tuna likely to be higher than average; tuna is a high value product and ‘browning’ can lead to rejection by customers while still in date.

**Notes**
1) Overall tuna has relatively low waste arisings due to prevalence of long shelf-life ambient products.
2) Processing comprises repackage and cut to size i.e. low waste operations.
3) Insufficient survey data obtained to estimate processing waste
4) 3% figure of tuna processing and wholesale waste from previous study used.

**Imports**
93% prepared or preserved (i.e. canned)
7% fresh or frozen; predominantly fillets and loins (assume 4% non-edible)

**Non-edible input ≈ 300tpa**

**Imports**
124,000tpa

**Foodservice**
35,000tpa ambient
1,300tpa fresh

**Overall Inputs**
124,000tpa

**Processing/Wholesale**
6,200tpa/2,500tpa
(Excludes prepared and preserved products)
Minimal processing of tuna takes place within UK

**Retail**
74,800tpa
>96% ambient, 3% fresh

**Consumer**

**Imports**
£283m.
93% prepared or preserved (i.e. canned)
7% fresh or frozen; predominantly fillets and loins (assume 4% non-edible)

**Non-edible input ≈ 300tpa**

**Processing waste & co-product generation**
1) No filleting of tuna takes place in UK.
2) Processing comprises repackage and cut to size i.e. low waste operations.
3) Insufficient survey data obtained to estimate processing waste
4) 3% figure of tuna processing and wholesale waste from previous study used.

**Retail waste & co-product generation**
1) Overall tuna has relatively low waste arisings due to prevalence of long shelf-life ambient products.
2) Waste levels for fresh tuna likely to be higher than average; tuna is a high value product and ‘browning’ can lead to rejection by customers while still in date.
2.3.6 Summary of pelagic fish

Resource mapping of pelagic fish supply chains allows us to conclude that:

- The majority of herring and mackerel entering the UK are exported with minimal processing.
- Significant volumes of non-edible by-products are produced by herring and mackerel processing, with the biggest source being from filleting operations.
- The majority of these non-edible processing outputs are utilised as a valuable co-product through sales to fishmeal plants; estimated as 95% co-product utilisation.
- Consequently, disposal of pelagic processing by-products as waste is extremely minimal.
- Within the margin of error of our estimates, and the unknown error margins inherent in estimates of export format, it is not possible to estimate quantities of avoidable waste in the supply chain.
- Minimal unavoidable and avoidable waste arises in tuna processing due to the prevalence of pre-processed inputs and limited processing undertaken in the UK.
2.4 Salmon and trout resource maps

2.4.1 Key issues for salmon and trout
Salmon and trout are both species with considerable UK aquaculture industries. Waste generation within aquaculture is outside the scope of this study, but an overview of existing work has been presented in Chapter 1. Aquaculture also gives rise to large volumes of salmon exports, which will have a significant impact on the supply chain for this species.

Salmon and trout are both gutted in aquaculture, and the primary input to UK processing is therefore gutted fish. For both species, an edible portion of 63% for a gutted fish has been used in our analysis.

As with other types of finfish, the most significant waste and co-product generation stage undertaken for salmon and trout is filleting, which gives rise to large quantities of non-edible components. This material is predominantly disposed of to fishmeal plants for production of animal feed, and generates both valuable secondary products and a source of income for the processor.

Other mechanisms for deriving value from non-edible portions of salmon are also used, for example salmon frames (skeletons) may be sold for production of flavour in other food products.

2.4.2 Estimates of processing waste & co-products
Using a similar approach to white fish and pelagics, an average figure for a ‘filleting’ processor and a ‘non-filleting’ processor have been derived from project data on salmon and trout. As for pelagics, the data set for salmon and trout used to create these estimates was significantly smaller than for white fish, and larger margins of error have therefore been obtained.

The accuracy of these estimates is limited by several factors, as follows:

- Figures for ‘average % processing waste and co-products’ are derived across both salmon and trout. Some species-specific variations will therefore be lost.
- The extrapolated processing estimates are based on figures for supply chain inputs from other sources (aquaculture and imports). The margins of error in these figures are not known.
- The derivation of a figure for processing assumes that all inputs pass through processing rather than wholesale. This may therefore result in an overestimate of processing waste and co-products.
- Quantities of exported edible and non-edible portions are based on assumptions on the format of exported fish.
- It is assumed that all salmon and trout are gutted within aquaculture. These by-products (approx. 10% of whole fish) have not been included in the resource maps.
- It is assumed that the edible portion of a gutted salmon or trout is 63%.
- Estimates of wholesale waste are not specifically included. However, as noted above, this should be over-compensated for by the assumption that all material passes through processing.

The quantity of non-edible material inputs can be treated as an estimate of the unavoidable waste which would be expected to occur within supply chains. This estimate does not include possibly avoidable waste from edible material, which is not commercially viable to remove. However, it is believed that waste of this type is extremely minimal, as filleting is highly effective in removing all edible material from the fish.

2.4.3 Salmon

The input: output chart, Figure 22, and resource map, Figure 23, summarise the inputs and outputs to the salmon supply chain and highlight the issues which contribute to waste and co-product generation.

The following points are noted:

- Salmon is a highly significant and high volume species within the UK market.
- The salmon supply chain is complicated and incorporates a wide range of processing operations.
- The majority of inputs are as ‘fish’ and therefore require filleting at some later stage of the supply chain.
A high volume of salmon is exported with minimal processing, so a substantial quantity of non-edible material will be manifest outside the UK.

Although an average retail waste figure of 5% has been used in the resource map, salmon retail waste may in reality be lower. One retailer quoted a figure of 1% waste for high volume, stable demand species such as salmon.

Figure 22 shows a good correlation between non-edible inputs and waste and co-product outputs, indicating that avoidable waste within the supply chain is relatively low. However, there will be additional sources of waste not captured in this chart, which may make total salmon arisings higher than the figure quoted. For example, the most common material sourced by fishmongers is whole salmon, which will result in additional non-avoidable waste in retail. Some multiple fish counters also source whole salmon. Some non-edible materials will also end up with foodservice or consumers, due to final products being served with skin or bones.

The discrepancy between the total volume of inputs and outputs may be due to inaccuracies in estimates of materials volumes; for example, quantities of salmon from aquaculture are derived from a 2007 survey.  

Figure 22: Summary of inputs and outputs to salmon supply chain
Figure 23: Salmon resource map

Overall Inputs
192,300tpa

Processing 133,800tpa
(excludes direct exports)
Wide range of primary and secondary processing operations

Retail 49,800tpa
64% fresh, 12% frozen, 24% ambient

Consumer

Imports
68,100tpa
Aquaculture
124,200tpa
Exports
72,200tpa
Foodservice
60m servings

Wastes & Co-Products

Notes

Aquaculture: £350m, fish gutted in aquaculture
Imports: 53% “fillets” / 47% “fish” (£264m)
Overall: 20% of inputs “fillets” (all edible); 80% “fish” assumed gutted fish with non-edible content 37%.

Non-edible input ≈57,800tpa

Average processing co-product & waste levels for salmon and trout: filleting processors 33%, non-filleting processors 3%.

Processing waste & co-product generation
- Filleting produces high volumes of non-edible components.
- A significant proportion of this material is utilised as a co-product and sold to fishmeal plants. However, this proportion cannot be quantified.
- Salmon heads and skeletons may be sold for use in production of secondary food products.

Exports: £300.0m, 81% “fish” (37% non-edible), 19% “fillets” ≈ 21,600tpa exported non-edible material

Retail waste & co-product generation
1) Salmon is a high volume retail product so lower waste levels than other species may be expected; real value may therefore be lower than estimate.
2.4.4 Trout

The input: output chart, Figure 24, and resource map, Figure 25, summarise the inputs and outputs to the trout supply chain, and highlight the issues which contribute to waste and co-product generation.

The following points are noted:

- Trout is predominantly derived from UK aquaculture and enters processing as gutted fish.
- No data exists on import or export volumes for trout; this may result in inaccuracies in the input: output mass balance shown in Figure 24.

As for salmon, there will be additional sources of trout waste that are not captured by our analysis. This will include unavoidable processing waste from fishmongers who predominantly purchase whole fish.

**Figure 24:** Summary of inputs and outputs to trout supply chain
Figure 25: Resource Map for Trout

- **Aquaculture**: fish gutted in aquaculture
  Assume all inputs are gutted fish with non-edible content 37%.
  Non-edible input ≈ 5,300tpa

- **Processing 14,400tpa**
  (excludes direct exports)
  Wide range of primary and secondary processing operations
  4,700 ± 1,200tpa

- **Retail 4,300tpa**
  99% fresh
  ≈ 200tpa

- **Foodservice**: 7m servings

- **Exports**: no data

**Notes**

- **Average processing co-product & waste levels for salmon and trout**: filleting processors 33%, non-filleting processors 3%.

- **Processing waste & co-product generation**
  1) Filleting produces high volumes of non-edible components.
  2) A significant proportion of this material is utilised as a co-product and sold to fishmeal plant. However, this proportion cannot be quantified.

- **Retail waste & co-product generation**
  1) Majority of trout product are fresh, resulting in a proportionately higher volume of waste relative to sales volumes.
2.4.5 Summary of salmon and trout

Resource mapping of salmon and trout supply chains allows us to conclude that:

- Inputs from aquaculture contain a high proportion of non-edible material, and inevitably result in production of waste and co-products within processing.
- The most significant source of waste and co-product generation within these supply chains is non-edible material from filleting.
- It is assumed that the majority of non-edible material generated within processing is sold for utilisation in fishmeal plants; it has not, however, proved possible to quantify this proportion.
- The margins of error for salmon and trout processing figures are relatively high based on use of a small data set. It is therefore not possible to estimate quantities of avoidable waste within these supply chains.
- A significant source of UK waste not captured by this analysis may be unavoidable waste from fishmongers and fish counters, as whole fish represent a significant proportion of salmon and trout purchased.
2.5 Shellfish resource maps

2.5.1 Key issues for shellfish

Eight species of shellfish, representing the major species of significance to UK markets, have been examined in this study. These eight species, crab, scallop, nephrops, cold water prawns, warm water prawns, mussels, whelks and cockles, have very diverse supply chains and, where possible, data has been collected on a species-specific basis.

As observed for finfish, the quantity of unavoidable waste and co-products derived in shellfish supply chains is highly dependent on the quantity of non-edible material in the inputs. Table 9 summarises the edible portions of key shellfish species. For all shellfish species, the high proportion of non-edible components means that processing operations to extract the edible material will inherently generate large volumes of by-products.

Table 9: Edible portions of shellfish species

<table>
<thead>
<tr>
<th>Species</th>
<th>Edible portion (as proportion of landed / gutted weight)</th>
<th>Non edible portion (as proportion of landed / gutted weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Products / description</td>
<td>%</td>
</tr>
<tr>
<td>Crab</td>
<td>White meat</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Brown meat</td>
<td></td>
</tr>
<tr>
<td>Scallops</td>
<td>Meat</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Roe</td>
<td></td>
</tr>
<tr>
<td>Nephrops &amp; prawns</td>
<td>Tail meat</td>
<td>24</td>
</tr>
<tr>
<td>Mussels</td>
<td>Mussel meat</td>
<td>14</td>
</tr>
<tr>
<td>Whelk</td>
<td>Whelk meat</td>
<td>42</td>
</tr>
</tbody>
</table>

The major supply chain inputs, processing stages and product types for each species will also have a significant influence on the quantity of waste generated within the supply chain. Table 10 summarises these factors for the species of interest to this project.

Table 10: Summary of supply chain structure for shellfish

<table>
<thead>
<tr>
<th>Species</th>
<th>Major format entering UK supply chain</th>
<th>Major processing Stages¹</th>
<th>Major products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crab</td>
<td>Whole live crab</td>
<td>Picking, Cooking, Vacuum packaging</td>
<td>White crab meat, Brown crab meat, Pates</td>
</tr>
<tr>
<td>Scallop</td>
<td>Whole live scallops</td>
<td>Shucking, Grading</td>
<td>Natural scallops; may be in shell</td>
</tr>
<tr>
<td>Nephrops</td>
<td>Whole, Heads &amp; claws removed at sea</td>
<td>Grading, Peeling, Breading &amp; battering</td>
<td>Large volume retail and foodservice, Scampi</td>
</tr>
<tr>
<td>Cold Water Prawns</td>
<td>Cooked &amp; peeled prawns, Smaller amounts raw or in shell</td>
<td>Cooking, Repackaging</td>
<td>Natural CWP, Prepared CWP, Foodservice include prawn cocktail</td>
</tr>
<tr>
<td>Warm Water Prawns</td>
<td>Raw in shell, Raw peeled</td>
<td>Cooking, Repackaging, Breading &amp; battering</td>
<td>Natural king prawns in retail and foodservice (may be in shell)</td>
</tr>
<tr>
<td>Mussels</td>
<td>Whole live mussels</td>
<td>Grading, Vacuum packaging, Cooking</td>
<td>Natural products, Mussels in sauces, Often in shell.</td>
</tr>
</tbody>
</table>

¹) Focus on stages where waste generation expected to occur; additional operations such as chilling, freezing and thawing are common to many shellfish species.
2.5.2 Shellfish waste estimates

For shellfish, the most significant waste-generating step is the removal of the edible portion of fish from the shell. This stage is known as ‘picking’ for crab, ‘shucking’ for mussels and scallops, and ‘peeling’ for prawns and nephrops. Processors were therefore divided according to whether or not they carried out these operations and, for example for crab, averages for ‘non picking’ and ‘picking’ processors were obtained.

Due to the high level of variation seen between the edible portions of different species of shellfish, the only robust approach to estimate processing waste was considered to be on a species-specific basis.

However, this approach limits the companies who can be used to generate this estimate to those who only process one main species of shellfish and can also provide data on shellfish waste volumes. The data set for some species was consequently very small, and, due to considerable variability in respondent responses, it did not prove possible to generate robust processor estimates for CWP, WWP or mussels. Resource maps have been included for these species to illustrate the likely main sources of waste. However, summaries of inputs and outputs have not been produced due to the lack of available data.

Only a very limited number of responses from companies processing whelks and cockles were captured by the telephone survey (Table 2). Due to this lack of information, resource maps have not been prepared for these two species.

Where estimates of processing wastes have been derived, the following limitations must be considered as regards accuracy:

- The extrapolated processing waste estimates are based on figures for supply chain inputs from other sources (landings and imports). The margins of error in these figures are not known.
- The derivation of a figure for processing waste assumes that all inputs pass through processing rather than wholesale. This may therefore result in an overestimate of processing waste.
- Assumptions have been made on the format of exported and imported shellfish. These assumptions use information from custom codes, but these do not provide complete information. For example, codes do not confirm whether a product is in-shell or not. Assumptions have therefore been made on the quantity of non-edible portions contained.
- Estimates of wholesale waste are not specifically included. For some species of shellfish (e.g. prawns), wholesale represents a major route to market. However, this should be over-compensated for by the assumption that all material passes through processing.
- Due to the necessity to treat all species independently, the data sets used to derive processing waste estimates are relatively small. The margin for error within these estimates is therefore quite high in some instances.

2.5.3 Co-products vs. wastes

For shellfish supply chains, differentiating between material which should be classified as a waste or a co-product presents a genuine challenge. Within finfish processing, the majority of non-edible material can be clearly designated as a co-product, as processors receive an income from selling this material to fishmeal plants and are clear that this is its end destination. However, the situation for shellfish processors is much less clear-cut. A small number of processors are successful in selling shell for use as aggregate or for decorative purposes, whereas many others will have to pay for the material to be taken away for use in similar applications. The first processor would doubtless view this material as a co-product as he derives value from it, whereas the second would view the material as a problematic waste.

In other instances processors will not know the end destination of the material they produce, as they may pay an intermediary to collect it from them. The processor consequently has no visibility of whether the material is later used (co-product), recovered through mechanisms such as composting or disposed of.

In this study it has therefore proved impossible to accurately classify the volumes of shellfish material which fall into these two categories. In the majority of instances the processors view the material as a waste, as they have to pay for its removal, and the term ‘waste’ is therefore predominantly used throughout this section to reflect these views. Where clear examples of co-product utilisation were identified, they have been included in the resource maps.
2.5.4 Crab

The input: output chart, Figure 26, and resource map, Figure 27, summarise the inputs and outputs to the crab supply chain, and highlight the issues which contribute to waste generation.

The following points are noted:

- The prevalence of whole crab inputs means a high proportion of non-edible components enter the UK supply chain. Most of this non-edible material is shell, which accounts for approximately 50% weight of a whole crab.
- A high proportion of this non-edible portion will leave the UK supply chain as exports of whole crab. The proportion attributed to this in Figure 27 is based on assumptions on export format, and may be subject to a significant margin of error.
- Some final products will contain non-edible components; for example dressed crab sold in shell.
- Most common products are crab meat (white or brown), with smaller quantities of value-added products, such as crab pâtés or dressed crab.
- The most significant waste generation stage is 'picking', which gives rise to a large volume of unavoidable waste, predominantly shell.
- Maximising picking yields is important to processors, and some commented that they use mechanical picking equipment to achieve this.
- Small quantities of edible but unavoidable waste will be created in the picking process due to small amounts of meat, which are uneconomic to extract.

The balance of inputs and outputs in Figure 26 shows a good correlation between edible inputs and output products. However, it must be noted that foodservice products are not included in this chart, and are likely to contribute a considerable volume to the product volume. The higher than expected products shown may therefore be influenced by the presence of non-edible components in products, but may also indicate that an overestimate of quantities of exported product has been made.

Disposal of shell represents a considerable challenge to crab processors. In South West England, where considerable crab processing is undertaken, a local ABPR compliant waste processor accepts this material, which is used for land application. In other regions of the country, the only compliant method available is to transport shell long distances for disposal to landfill. The high cost associated with this is not economically viable for many companies. In theory crab shell should be suitable for use in a range of applications, for example, in aggregate. However, these routes are not well developed and processors will generally have to pay to send shell for use in this type of application.

Some crab shell can be used in dressed crab products, although this option is only available for a minority of shells of a suitable size. However, the shell must be cleaned before it can be used and crab processors do not carry this out. Processors are paid for the shell (approx. 7p a shell), but they then have to buy cleaned shell back at a considerably higher cost (30-35p) to use in products. It can be more cost effective for processors to use imitation ‘plastic crab shells’ than real shells. There is also a trade in imported shells from China, where they have been cleaned to standards designated as free of flesh and sterilised to specific hygiene standards.

Although there may be scope to facilitate use of UK-derived shells for dressed crab, it must be stressed that the majority of shell derived by processors is of unsuitable size. Alternative outlets must therefore be available for shell of other sizes, which currently is generally sent to landfill or land application.
Figure 26: Summary of inputs and outputs to crab supply chain

<table>
<thead>
<tr>
<th>Category</th>
<th>Outputs (tpa)</th>
<th>Inputs (tpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK Products</td>
<td>1,100</td>
<td>11,100</td>
</tr>
<tr>
<td>Exported Edible</td>
<td>10,000</td>
<td>10,700</td>
</tr>
<tr>
<td>UK Waste</td>
<td>6,800</td>
<td>9,000</td>
</tr>
<tr>
<td>Exported Non-Edible</td>
<td>9,000</td>
<td>17,700</td>
</tr>
<tr>
<td>Products</td>
<td>11,100</td>
<td>15,800</td>
</tr>
<tr>
<td>Waste</td>
<td>15,800</td>
<td></td>
</tr>
</tbody>
</table>

Output Breakdowns (tpa)

- UK Products: 1,100
- UK Waste: 6,800
Figure 27: Resource map for crab

**Imports** 3,000tpa

**Landings** 25,400tpa

**Exports** 19,000tpa

**Foodservice** no data

**Overall Inputs** 28,400tpa

**Processing 13,500tpa** (excludes direct exports) Predominantly picking operations to extract crab meat

**Retail 1,100tpa** 44% fresh, 53% ambient

**Consumer**

**Wastes & Co-Products**

**Landings:** primarily whole live crab (£32.4m)

**Imports:** 53% prepared or preserved, 47% range of formats.

**Overall:** 90% whole live (68% non-edible), 5% prep/preserved (all edible), 5% unknown format (assume average 34% non-edible).

**Non-edible input ≈17,700tpa**

**Notes**

**Average processing co-product & waste levels for crab:** picking processors 49%, non-picking processors 17%.

**Processing waste & co-product generation**

1) Picking removes edible component from shell: large quantity non-avoidable waste.

2) Yields optimised through use of machinery but small amounts of residual edible flesh not economic to remove.

3) Shell could potentially be utilised in a range of applications but these are not well developed; majority is currently disposed of as waste.

**Exports:** £75m, Assumptions of 70% whole crab (68% inedible), 30% processed (all edible) ≈ 9,000tpa exported non-edible material

**Retail waste & co-product generation**

- Crab products may contain some non-edible components; e.g. dressed crab in shell so waste is passed to consumer.
- Waste levels of fresh crab may be higher than estimated as is a high value, low volume product.
2.5.5 Scallop

The input: output chart, Figure 28, and resource map, Figure 29, summarise the inputs and outputs to the scallop supply chain and highlight the issues which contribute to waste generation.

The following points are noted:

- The proportion of non-edible components entering the UK supply chain is very high. The most significant input is whole live scallops from UK landings, with only a 14% edible portion. The majority of this material, >65% of whole scallop, is shell.
- A significant proportion of this non-edible portion will exit the UK supply chain as exports of whole scallop. The proportion attributed to this in Figure 29 is based on assumptions on export format, and may be subject to a significant margin of error.
- Shucking (removal of edible portion from shell) is the major processing stage which generates waste within UK processing.
- Shucking wastes are predominantly unavoidable with minimal processing spillages. Manual shucking generally gives rise to lower wastage than mechanical processes.
- Some non-edible components of scallop may be contained in products; for example retailers or restaurants may sell scallops in shell.
- Most common products are shucked scallops, predominantly sold fresh or frozen for export.
- The discrepancy between the quantity of edible inputs and products outputs is likely to be due to the lack of foodservice data for scallops.

The large volume of shell produced by scallop processors makes disposal of this material a significant issue. Various methods of shell utilisation were reported by processors, including selling for decorative purposes (e.g. in gardens) or used as aggregate for forestry road construction. In some instances, these outlets represented a considerable source of income to the processor, whereas others processors had to pay to have shell taken away. As for all types of shell, the legislation applying to scallop shell can make these markets difficult to exploit. Although a significant amount of shell ends up being used in a range of markets, and could therefore be categorised as a co-product, most processors view shell as a waste as it incurs a cost for disposal.

Figure 28: Summary of inputs and outputs for scallop supply chain
Figure 29: Resource map for scallop

Inputs / Outputs

Imports
3,800tpa

Landings
28,400tpa

Exports
12,500tpa

Foodservice
no data

Overall Inputs
32,200tpa

Processing 22,800tpa
(excludes direct exports)
Predominantly shucking operations
to extract scallop meat

14,400±
6,900tpa

Retail 800tpa
63% fresh, 37% frozen

<100tpa

Wastes & Co-Products

Landings: primarily whole live scallops (£45.7m)
Imports: 10% live, fresh; 80% frozen, 10% other
Overall: 88% whole live (86% non-edible), 12% unknown format
(assume average 43% non-edible).

Non-edible input ≈ 26,000tpa

Average processing co-product & waste levels for scallop:
shucking processors 63%

Processing waste & co-product generation
1) Shucking removes edible component from shell: large
quantity non-avoidable waste (shell >65% of whole
scallop).
2) Shell is used in applications such as aggregate and
decorative uses but these outlets are still difficult to exploit.

Exports: £80m, Assumptions of 70% whole scallop (86% non-
edible), 30% processed (all edible)
≈ 7,500tpa exported non-edible material

Retail waste & co-product generation
- Scallop products may contain some non-edible components;
e.g. whole scallops in shell.
- Waste levels of fresh scallop may be higher than estimated
  as it is a high value, low volume product.
2.5.6 Nephrops norvegicus (common names include langoustine, Norway lobster, scampi)

The input: output chart, Figure 30, and resource map, Figure 31, summarise the inputs and outputs to the nephrops supply chain and highlight the issues that contribute to waste generation.

The following points are noted:

- A large proportion of material entering the UK supply chain is comprised of non-edible components due to UK landings of whole nephrops. Some processing of nephrops takes place at sea; however, this accounts for a relatively low proportion of the overall non-edible material.
- Accurate quantification of the quantity of non-edible material entering the supply chain is not possible, due to a lack of robust data on the extent of processing at sea. Figures within our model are extrapolated from a 2001 estimate of nephrops processing at sea.\(^5\)
- A significant proportion of the non-edible portion will exit the UK supply chain as exports of whole nephrops. The proportion attributed to this within Figures 30 and 31 is based on assumptions on export format, and may be subject to a significant margin of error.
- The most common nephrops product is scampi; sold either via retail or through foodservice.
- Breading is a common stage in nephrops processing, and breadcrumb waste streams will be produced.
- Final products are unlikely to contain any non-edible components.

The increased volume of products in comparison to edible inputs shown by Figure 30 may be due to the weight increase resulting from breading.

The quantity of waste accounted for within the resource map is considerably less than the estimated non-edible inputs. This may be due to inaccuracies in the estimate of processing waste, which contains a large margin of error. Assumptions made in calculating the non-edible proportions of landings, imports and exports may also contribute to this discrepancy. Given this large discrepancy between expected waste and estimated waste it is not possible to reach any conclusions about the quantities of avoidable waste. However, as noted for other species a focus on yield optimisation within processing is expected to result in these wastes being minimal.

The most significant waste stream derived from nephrops will be shell. Nephrops have a softer shell than species such as crab or scallop which is therefore less suitable for use in applications such as aggregate. The majority of shell produced is not utilised as co-products and is generally viewed as a waste by processors. Common outlets for this material include composting.

**Figure 30: Summary of inputs and outputs for nephrops supply chain**

<table>
<thead>
<tr>
<th>Inputs (tpa)</th>
<th>Outputs (tpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edible 14,700</td>
<td>Non-Edible 30,800</td>
</tr>
<tr>
<td>Products 22,300</td>
<td>Waste 18,800</td>
</tr>
<tr>
<td>Foodservice 7,700</td>
<td>Exported Edible 8,300</td>
</tr>
<tr>
<td>Exported Non-Edible 12,000</td>
<td>Retail 6,300</td>
</tr>
<tr>
<td>UK Waste 6,800</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 31: Resource map for nephrops

Overall Inputs
45,500tpa

landings: Whole live nephrops or may have heads and claws removed at sea (£97m)
imports: 82% frozen, 18% fresh; formats unknown
Overall: 93% landed nephrops (assume average 69% non-edible); 7% unknown format (assume 38% non-edible)
Non-edible input ≈ 30,800tpa

Processing 33,700tpa
(excludes direct exports)
Peeling and breading most significant operations.

6,700± 4,900tpa

processing waste & co-product generation
1) Peeling removes edible component from shell so based on edible content of 31% the expected higher waste arisings for this stage would be considerably higher than the survey average.
2) Common outlets for shell include composting.

Retail 800tpa
63% fresh, 37% frozen

Retail waste & co-product generation
1) Retail products mainly fully processed so no non-edible content.
2) Low levels of retail waste as predominantly frozen, long-life products.

Imports: £110.8m, assumptions of 50% whole (76% non-edible), 50% shell-on tails (42% non-edible)
≈ 12,000tpa exported non-edible material

Exports: £110.8m, assumptions of 50% whole (76% non-edible), 50% shell-on tails (42% non-edible)
≈ 12,000tpa exported non-edible material

Imports 3,200tpa

Landings 42,300tpa

Exports 20,300tpa

Foodservice 7,700tpa

Average processing co-product & waste levels for nephrops:
peeling processors 20%.
Previous studies indicate 15% weight increase in processing.¹¹

Non-edible input ≈ 30,800tpa
2.5.7 Cold water prawns

The resource map, Figure 32, summarises the inputs and outputs to the cold water prawn (CWP) supply chain, and highlights the issues contributing to waste generation. Available data on import and export combine all species of prawn, and it is therefore not possible to derive robust 'CWP-specific' volumes. In the absence of these figures an input: output chart for CWP has not been produced.

The following points are noted:

- All inputs to UK supply chains are from imports.
- CWP products arriving within the UK have often undergone pre-processing.
- Volumes of exports for these species cannot be quantified as data is only available collectively for all prawns and shrimps.
- The most common raw materials identified by processors and wholesalers within our study were cooked and peeled CWP.
- No processors reported peeling of CWP; generation within processing of unavoidable waste will therefore be low.
- Although insufficient data to produce an estimate of processing waste was obtained, processors generally reported low waste arisings (<5%).

CWP have a low waste supply chain within the UK, as the majority of processing waste and non-edible by-products are generated in the country of origin.

2.5.8 Warm water prawns

Considerable similarity exists between the supply chain for warm water prawns (WWP) and that discussed above for cold water prawns. The resource map in Figure 33 summarises this supply chain structure and highlights the main causes of waste. As for CWP, it is not possible to derive accurate figures for imports and exports and an input: output chart has not been produced.

The following points are noted:

- All inputs to UK supply chains are from imports.
- WWP products arriving within the UK may have undergone pre-processing.
- Volumes of exports for these species cannot be quantified as data is only available collectively for all prawns and shrimps.
- The most common raw materials identified by processors were raw shell-on and raw peeled WWP.
- The most common raw material identified by wholesalers was raw shell-on WWP.
- Only one processor reported peeling of WWP, with a waste level of approximately 40%, all other processors reported <5% waste arisings.
- A considerable volume of WWP will give rise to shell-on products; whole king prawns are a common retail and foodservice product.

WWP generate low waste within UK processing due to the limited processing undertaken. However, a considerable proportion of non-edible materials will be passed up the supply chain to consumers.
Figure 32: Resource map for cold water prawns

**Inputs / Outputs**

- **Imports**: Variable data
- **Exports**: No data
- **Foodservice**: 16,300tpa (all prawns)

**Wastes & Co-Products**

- **Overall Inputs**: 29,000-45,000tpa
- **Processing/Wholesale**: 35%/65%
  Limited processing undertaken within UK
- **Retail**: 18,000tpa
  - 66% fresh, 34% frozen
- **Consumer**: \( \approx 700 \) tpa

**Notes**

- **Imports**:
  - Data varies on import volumes from 29,000tpa to 45,000tpa.\(^{12}\)
  - Import formats for all prawns: 46% frozen, 52% prepared or preserved.
  - Impossible to quantify non-edible portion but will be very low due to prevalence of pre-processed inputs.

- **Processing waste generation**
  1) Main processing input is cooked and peeled prawns.
  2) No processors within survey carried out peeling therefore expect minimal unavoidable waste arisings.
  3) Most common processes: chilling, cooking, repackaging.
  4) Processors generally reported <5% waste arisings.

- **Retail waste & co-product generation**
  1) Retail CWP products predominantly processed so no non-edible content.
  2) CWP are high volume retail product so actual waste levels may be lower than estimated.

---

\(^{12}\) Variable data on import volumes from 29,000tpa to 45,000tpa.
Figure 33: Resource map for warm water prawns

**Imports**
≈48,000 tpa

**Exports**
no data

**Foodservice**
16,300 tpa (all prawns)

**Overall Inputs**
≈48,000 tpa

**Processing/Wholesale**
48,000 tpa
Limited processing undertaken within UK

**Retail**
15,300 tpa
66% fresh, 34% frozen

**Consumer**

**Wastes & Co-Products**

**Imports:** ≈£275m
- Import formats for all prawns; 46% frozen, 52% prepared or preserved.
- Impossible to quantify non-edible portion but assume some pre-processed prior to entering UK.

**Insufficient data to produce estimate of waste levels**

**Processing waste generation**
1) Variable inputs to processing; most common is raw in shell.
2) Only one processor reported peeling therefore expect minimal unavoidable waste arisings.
3) Most common processes: chilling, thawing, repackaging.
4) All processors (except one carrying out peeling) reported waste levels <5%.

**Retail waste & co-product generation**
- Retail (foodservice) WWP products may be sold in shell (e.g. whole king prawns) so will contain some non-edible material.
- WWP are high volume retail product so actual waste levels may be lower than estimated.

---

**Notes**

- Variable inputs to processing; most common is raw in shell.
- Only one processor reported peeling therefore expect minimal unavoidable waste arisings.
- Most common processes: chilling, thawing, repackaging.
- All processors (except one carrying out peeling) reported waste levels <5%.
- Retail (and foodservice) WWP products may be sold in shell (e.g. whole king prawns) so will contain some non-edible material.
- WWP are high volume retail product so actual waste levels may be lower than estimated.
2.5.9 Mussels

The resource map for mussels is shown in Figure 34, and highlights some of the issues which contribute to waste generation within the supply chain. Due to insufficient data, it was not possible to generate a robust estimate of processing waste and consequently an input: output chart has not been produced for this species.

The following points are noted:

- The majority of mussels enter UK processing as whole live animals.
- Processing of mussels is generally minimal and consists of grading and packaging.
- Only one processor reported shucking of mussels.
- Due to insufficient data it has not been possible to produce an estimate of processing waste, however, most mussel processors reported waste arisings of <5%.
- A high proportion of non-edible components will be passed up the supply chain to consumers.

Mussels have low waste arisings within the UK supply chain due to limited processing operations being undertaken.

2.5.10 Whelks

Whelks are another species which predominantly enters the UK supply chain as whole, live shellfish with a high proportion of non-edible component. Much of this non-edible component is produced as non-avoidable waste within processing, where the whole whelks are cooked and the edible portion removed. Whelks are typically sold as a processed / cooked product and are largely exported.

A resource map for whelks has not been produced due to a lack of data on this species from survey respondents.

2.5.11 Cockles

A resource map for whelks has not been produced due to a lack of data on this species from survey respondents.
**Figure 34: Resource map for mussels**

**Inputs / Outputs**
- **Landings** 2,700tpa
- **Aquaculture** 26,100tpa\(^{16,17}\)
- **Exports** no data
- **Foodservice** 14m servings

**Overall Inputs** 28,800tpa

**Processing/Wholesale** 28,800tpa
- Minimal processing carried out to extract meat, secondary processing to value-added products

**Retail** 4,300tpa
- 88% fresh

**Wastes & Co-Products**
- **Landings**: whole live mussels (£0.3m)
- **Aquaculture**: whole live mussels
- **Overall**: Predominant input is whole live mussels (86% non-edible)
  - Non-edible input \(\approx 24,800\)tpa

**Notes**
- Insufficient data to produce estimate of waste levels
- **Processing waste generation**
  1) Main processing input is whole, live mussels so large amounts of non-edible material enter processing.
  2) Only one processor (of 12) reported shucking so majority of products reach market in shell.
  3) Most common processes: chilling, grading, vacuum packaging.
  4) Based on these operations expect low waste arisings; most processors report <5% waste.

**Retail waste & co-product generation**
- 1) Retail (and foodservice) products will frequently be whole mussels in shell; non-edible material ends up with consumer.
2.5.12 Shellfish summary and conclusions

The considerable diversity of shellfish supply chains means that the extent and causes of waste are very species-specific. Many of the conclusions reached from resource mapping of shellfish supply chains are likewise species-specific.

The findings from analysis of the shellfish supply chain are as follows:

- All whole shellfish species contain a large proportion of non-edible components, and will therefore generate considerable non-avoidable waste or co-products at some point within their supply chain.
- Crab, scallop and nephrops are predominantly derived from UK landings of whole animals and considerable processing takes place within the UK.
- Picking of crab, shucking of scallops and peeling of nephrops results in large volumes of unavoidable waste within the UK.
- Avoidable waste from picking, peeling and shucking operations is minimal due a focus on yield maximisation driven by the high value of products.
- Although numerous options theoretically exist for utilisation of shell, legislation makes it difficult for processors to exploit these outlets.
- disposal of shell represents a significant cost for shellfish processors, notably crab, scallop, whelk and nephrops processors. Although some of this material may eventually be utilised in applications such as aggregate, it is generally viewed by the processor as a waste due to the costs incurred for disposal.
- Prawns undergo minimal processing and consequently result in low waste arisings within the UK.
- For CWP, the majority of processing takes place in the country of origin.
- For WWP, processing may take place in country of origin, or minimally processed products end up as final products (e.g. whole king prawns).
- Mussels enter UK processing as whole animals but frequently end up as products with minimal processing; for example, whole mussels sold either in sauces or in natural state. Mussel processing waste is therefore low.

The most significant conclusion arising from discussions with shellfish processors in this project is that there is an issue with the inclusion of shell in the scope of ABPR and other environmental legislation. This has made it more difficult to develop alternative uses for shell. In some instances, this material is currently disposed of to landfill due to the legislative complexities involved in exploiting other outlets. There is considerable scope to assist the industry in addressing the legislative framework, and facilitating the development of increased outlets for shell utilisation. Shell is classified as Category 3 ABP and must therefore be designated free-of-flesh before it can be utilised. The cost of this treatment, and the current lack of clarity on what exactly constitutes free-of-flesh, often mean exploitation of potential markets for shell is either non-commercially viable or too legislatively complex for producers.

2.6 Resource map summaries & conclusions

The 17 resource maps contained in this report illustrate the variability that exists between waste arisings and co-product utilisation for different seafood species. This variation can be attributed to a range of factors, including the types of end product and the processing stages undertaken. However, the factor that has the greatest influence on the overall quantity of waste and co-products is the format of raw material entering the UK supply chain, and the quantity of non-edible material contained within this.

A key aim of these resource maps was to estimate the quantity of avoidable waste created at various stages of the supply chain. While it is reasonable to assume that the estimates of retail waste quoted in these resource maps equate to predominantly avoidable waste, deriving a similar figure for processing waste is more challenging.

To obtain a figure for the quantity of avoidable processing waste, it is first necessary to derive an accurate figure for non-avoidable waste. Unfortunately this figure is not a simple one to obtain, as a detailed understanding of import, export and landing formats, as well as the species-specific edible portion, is required. All available data on these factors has been used in the current study to create the estimates of non-edible inputs quoted in the resource maps. However, the error inherent within these data sources is unknown.

Many processors have very variable operations, processing a wide range of species and utilising a range of fish formats. In the absence of detailed waste audits, it is not possible to confidently assign a figure for the unavoidable waste that would be expected in their operations. Considerable variations also exist between processors, making it difficult to generate a robust industry-wide average. The impact of this variability is apparent in the large margins of error present in some processing waste estimates.
The high proportion of non-avoidable wastes, coupled with the errors inherent in estimating processing waste, make it impossible to quantify avoidable processing waste arising. Quite simply, these relatively small volumes are 'lost in the noise' of the much higher non-avoidable volumes. For many species, the estimate of total supply chain waste and co-products is less than the volume of non-edible inputs. This can be attributed to several factors:

- Not all sources of waste arisings are included in our estimate.
- Some non-edible components will be passed up the supply chain to consumers.
- Errors in estimating the non-edible material contained in imports and exports.

For resource maps where data on all key outputs (retail, foodservice and export) are available, a comparison of the quantity of edible inputs and output products provides an indication of the extent of avoidable waste arisings. Generally this supports the view that avoidable waste generation is low. This is in accordance with the view frequently presented by respondents that fish is too valuable a commodity to waste.

Summary conclusions on waste and co-product generation within these resource maps can be drawn, as follows:

- The majority of waste and co-products created in supply chains are unavoidable, non-edible components.
- A processor’s waste and co-product generation is highly dependent on the operations carried out. Those carrying out filleting of finfish or picking/shucking/peeling of shellfish will inevitably have higher arisings than other processors.
- Waste and co-product generation is highly dependent on species and input format; two primary processors of haddock may have very different arisings depending on whether their primary raw material format is fillets or whole fish.
- Quantities of avoidable waste within processing cannot be estimated, as these relatively small volumes are ‘lost in the noise’ of the much higher non-avoidable waste arisings.
- A comparison of edible inputs and product volumes indicates that avoidable waste arisings within processing are generally low.
- Within finfish processing, the majority of non-edible by-products are sold to fishmeal plants, and as such may be considered as co-products which represent a valuable source of income to the processor.
- Within shellfish processing, finding suitable outlets for shell presents a considerable challenge to processors, and, despite a range of potential applications, this material is generally not well exploited as a co-product.
3.0 Processing and wholesale – wastes and co-products

3.1 Generation of processing wastes and co-products
The resource maps presented in Chapter 2 provide estimates for the quantity of waste and co-products generated within processing for individual species. Quantities of waste and co-products are combined into a single figure. An approximate disaggregation of this figure into co-products, which represent a value to the producer, and wastes, which are disposed of at a cost to the producer, is included in resource map notes and then discussed further. In this study the distinction between co-products and waste is considered to be whether the material generates a value to the producer. All approaches which constitute a cost are therefore designated as waste disposal routes, and this category therefore includes both disposal to landfill and environmentally beneficial routes, such as composting and AD. Although these methods could more accurately be considered as recovery rather than disposal, the key criterion is that the producer views this as waste disposal and incurs a cost. It is noteworthy that the same material may be viewed as a valuable co-product by one producer but as a waste by another, due to the availability of suitable outlets for the material.

The resource maps also present estimates of the quantity of unavoidable waste expected to arise within these supply chains, based on existing information on formats of raw materials and edible portions of fish. In theory, comparison of this quantity of expected unavoidable waste with estimates of waste and co-products from processing and exports, should enable an estimate to be obtained for the quantity of avoidable waste generated in processing. However, due to the high variability in operations, these estimates of processing waste and co-products generally incorporate a large margin of error. The high levels of unavoidable waste for many species mean that the comparatively small quantities of avoidable waste cannot be identified. Consequently, it is not feasible to produce a robust estimate of the quantities of avoidable waste produced.

3.2 Wholesale waste generation
A total of 61 wholesalers provided data to the telephone survey. However, only ten of these companies were able to provide sufficient data to enable a percentage waste figure to be derived. Within this sub-set, considerable variations were observed, with figures varying from 0-67% waste. As several of these respondents identified themselves as being both wholesalers and fishmongers, it is not possible to assign the proportion of waste derived from each of these operations. Additionally, wholesalers may undertake some processing operations, providing a large amount of variability in the percentage of waste that would be expected within individual operations.

Based on this small data set and the high level of variability within it, no attempt was made to produce an extrapolated estimate of waste arisings within the wholesale sector. For most species of interest to this study, wholesale represents a relatively small proportion of the supply chain, and will consequently be responsible for a relatively small proportion of waste arising throughout the supply chain.

3.3 Waste disposal and co-product utilisation mechanisms
Disposal mechanisms vary according to the type of fish processed. The main disposal and co-product utilisation mechanisms by type of fish are outlined below. All fish-derived by-products must be treated in compliance with ABPR. 18, 19 The majority of fish by-products are classified as Category 3 ABP, and must be disposed of in accordance with the methods specified by ABPR. Permitted methods include incineration and rendering, plus AD and composting subject to pasteurisation criteria being met. Landfill of Category 3 materials is not permitted under ABPR. 20

3.3.1 White fish
Analysis of data provided by white-fish processors was carried out to obtain an overview on the standard methods of waste disposal or co-product utilisation, and the associated costs or value. In total 26 processors identified themselves as only handling whitefish and provided a breakdown of material outlets. Analysis of this data led to the following observations:

- 77% of white fish waste/co-products from processors was sent to fishmeal.
- 81% of white fish waste/co-products from primary processors was sent to fishmeal.
- Average value derived for material sent to fishmeal was £50 per tonne.

Additional mechanisms for utilisation of white fish co-products include salting and drying of, for example, fish heads for export to African markets. Two secondary white fish processors commented that fishmeal sites will not accept material that is contaminated by large amounts of batter or breadcrumbs, and that other outlets, e.g. rendering, must be used for this material.
3.3.2 Pelagic fish, salmon and trout

The majority of processing waste/co-products from pelagic fish, salmon and trout will also be sold to fishmeal plants. However, due to the smaller subset of pelagic or salmon-only processors, it is not possible to quantify this proportion. The value derived by processors for sale of pelagic co-products to fishmeal is generally higher than for white fish due to the high oil content of pelagic fish, which is more valuable to the fishmeal process.

Although a figure could not be derived from the current study, Seafish’s industry knowledge suggests that a figure of at least 95% co-product utilisation in fishmeal would be realistic for pelagic fish. The situation for salmon and trout is less clear, and it is impossible to estimate the proportion of co-product utilisation for these species.

In addition to use as fishmeal, other uses exist for salmon. One large salmon processor commented that all their fish heads and bones were sold to secondary processors for production of food products.

3.3.3 Shellfish

Shellfish processing results in production of two main types of waste: shell and flesh waste including viscera. This waste is largely unavoidable and is driven by the high non-edible portion of many species. Waste generation is particularly high for species such as crab, whelk, nephrops and scallop, where the standard input to UK processors is whole shellfish.

Some processors will treat these two streams separately. Shell can be considered a co-product, and may be used in a range of applications including aggregate for road building or for decorative purposes, and may generate a small income for processors. However, these markets are not very well developed and shell may frequently be combined with flesh waste and disposed of at a cost to processors.

A range of alternative outlets are available for shell which is not used in the applications noted above. Likewise, a wide range of treatment methods is used for viscera and flesh waste from shellfish processing. For both materials, the most common treatment methods include landfill and composting, with a small number of respondents stating that waste was incinerated or used for bait. Costs quoted by shellfish processors for landfill of waste ranged from £50-£100 per tonne. It should be noted that landfill of untreated by-products is not an approved method according to ABPR. However, this method is permitted in some areas due to a lack of other options.

A number of shellfish respondents to the telephone survey stated that they used ‘other methods’ of disposal, but these alternative methods were not defined.

3.4 Waste disposal issues within processing and wholesale

Overall 75 companies (27%) from the telephone survey and detailed interviews said waste disposal was a problem for them. This included issues relating to both packaging and seafood waste. Those who identified waste disposal as being a problem were asked to specify the main reasons. The most significant answers are shown below:

- Cost (79%).
- Limited choice of disposal options for seafood waste (35%).
- Limited choice of disposal options for packaging waste (25%).
- Effect of legislation e.g. ABPR (11%).

It should, however, be noted that in many instances these reasons are interdependent. For example, the high cost and limited choice of disposal options is frequently driven by the need to meet legislative requirements such as ABPR.

This dataset was then used to investigate how types of operation and company location influenced the experiences of processors concerning waste disposal.

3.4.1 Influence of type of operations

Table 11 provides a breakdown by type of fish handled. Previous work has shown that shellfish companies experience considerably more problems with waste disposal than finfish companies. This is driven by the high quantity of unavoidable waste which occurs in many shellfish operations, and also the fact that fishmeal plants will generally not accept shellfish waste. Disposal of both shell and flesh waste can be a problem for these
companies. The current data supports this previously observed trend, and shows that the percentage of companies who experience problems with waste disposal is considerably higher for those handling shellfish.

Table 11: Percentage of companies who identified waste disposal as being a problem

<table>
<thead>
<tr>
<th></th>
<th>Processors &amp; wholesalers</th>
<th>Processors</th>
<th>Processors &amp; wholesalers (excluding packaging problems)¹</th>
<th>Processors (excluding packaging problems)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shellfish only</td>
<td>36%</td>
<td>38%</td>
<td>34%</td>
<td>36%</td>
</tr>
<tr>
<td>White fish only</td>
<td>15%</td>
<td>15%</td>
<td>11%</td>
<td>10%</td>
</tr>
<tr>
<td>No shellfish (finfish only)</td>
<td>21%</td>
<td>20%</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>Shellfish (includes those also handling finfish)</td>
<td>40%</td>
<td>37%</td>
<td>36%</td>
<td>33%</td>
</tr>
<tr>
<td>Overall</td>
<td>29% (73)</td>
<td>28% (55)</td>
<td>24% (61)</td>
<td>23% (46)</td>
</tr>
</tbody>
</table>

1. Companies whose answers indicated that their predominant problem with waste disposal was related to packaging waste were excluded from this subset.

Where companies had specifically stated that their waste disposal problems were due to the effect of legislation, or a lack of options for seafood waste disposal, the breakdown of responses shown in Table 12 was obtained. This shows that these issues were predominantly experienced by shellfish companies. This result is also summarised in Figure 35, which shows the number of companies within each sector who cited these issues, weighted according to the size of sector.

Table 12: Percentage of companies where lack of seafood disposal options or the effect of legislation caused problems with waste disposal.

<table>
<thead>
<tr>
<th></th>
<th>Processors &amp; wholesalers</th>
<th>Processors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shellfish only</td>
<td>25%</td>
<td>28%</td>
</tr>
<tr>
<td>White fish only</td>
<td>2%</td>
<td>0%</td>
</tr>
<tr>
<td>No shellfish (finfish only)</td>
<td>7%</td>
<td>6%</td>
</tr>
<tr>
<td>Shellfish (includes those also handling finfish)</td>
<td>21%</td>
<td>21%</td>
</tr>
<tr>
<td>Overall</td>
<td>12% (31)</td>
<td>13% (25)</td>
</tr>
</tbody>
</table>

Figure 35: Companies citing lack of seafood disposal options or legislation as reason for waste disposal problems. Results are weighted by sector size.

3.4.2 Influence of location
The number of companies who experienced problems with waste disposal was broken down according to geographical location (see Table 13). Wales and the Midlands were excluded, as the overall dataset only
incorporated a small number of companies in each of these regions (seven in Wales and 11 in the Midlands). This data highlights the fact that problems of waste disposal are strongly related to geographical location, and are based on the availability of suitable and cost effective disposal options.

**Table 13: Influence of geographical location on waste disposal problems**

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of respondents (wholesalers &amp; processors)</th>
<th>Percentage of respondents where waste disposal is a problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotland</td>
<td>87</td>
<td>37%</td>
</tr>
<tr>
<td>North East</td>
<td>51</td>
<td>18%</td>
</tr>
<tr>
<td>North West</td>
<td>15</td>
<td>13%</td>
</tr>
<tr>
<td>Northern Ireland</td>
<td>12</td>
<td>33%</td>
</tr>
<tr>
<td>South East</td>
<td>25</td>
<td>36%</td>
</tr>
<tr>
<td>South West</td>
<td>41</td>
<td>37%</td>
</tr>
<tr>
<td>Overall</td>
<td>249</td>
<td>29%</td>
</tr>
</tbody>
</table>

This data was then further broken down according to the types of fish handled by companies in different locations. Table 14 shows this breakdown and illustrates the fact that problems associated with waste disposal are both regional and based on type of operations. The most significant problems are experienced by shellfish processors in regions such as Scotland and the South West.

**Table 14: Influence of geographical location and type of operations**

<table>
<thead>
<tr>
<th>Region</th>
<th>Fish handled¹</th>
<th>Number of companies</th>
<th>% reporting waste problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotland</td>
<td>Shellfish</td>
<td>34</td>
<td>53%</td>
</tr>
<tr>
<td>Scotland</td>
<td>Finfish</td>
<td>54</td>
<td>26%</td>
</tr>
<tr>
<td>North East</td>
<td>Shellfish</td>
<td>16</td>
<td>19%</td>
</tr>
<tr>
<td>North East</td>
<td>Finfish</td>
<td>33</td>
<td>18%</td>
</tr>
<tr>
<td>South West</td>
<td>Shellfish</td>
<td>23</td>
<td>48%</td>
</tr>
<tr>
<td>South West</td>
<td>Finfish</td>
<td>18</td>
<td>22%</td>
</tr>
<tr>
<td>South East</td>
<td>Shellfish</td>
<td>17</td>
<td>47%</td>
</tr>
<tr>
<td>South East</td>
<td>Finfish</td>
<td>8</td>
<td>13%</td>
</tr>
</tbody>
</table>

¹) Companies identified within this table as shellfish processors includes those who processed only shellfish and companies processing both shellfish and finfish

3.4.3 Reasons for difficulties with waste disposal

Discussions with a range of companies, both in detailed interviews and a series of telephone survey follow-up interviews, helped to clarify some of the reasons for waste disposal problems. As the data above shows, shellfish companies predominantly experienced the greatest problems, with company location also playing a significant role.

**Availability of disposal options:** Discussions with companies highlighted that these problems are often due to remoteness of location coupled with a lack of available outlets. Some respondents stated that their nearest ABPR-compliant facility was in excess of 50 miles away, thereby making it not cost effective for them to use. In some instances, companies admitted that they were currently disposing of waste by methods which they were aware did not fully comply with legislative requirements. Companies generally stressed that they would like to operate in accordance with legislation; however, cost effective options to enable them to do this were not available.

**Regional variability:** In some regions, disposal mechanisms that are not strictly ABPR-compliant are accepted by regulators due to the lack of available alternatives. There was a view from some respondents that individual regulators will apply the rules differently. Although this can be argued to constitute a pragmatic approach, it can also give rise to different standards being applied in different regions of the country. This approach, coupled with the variability of disposal costs between regions, resulted in some companies feeling that a lack of readily available disposal options put them at a competitive disadvantage versus companies in other areas. Some companies also expressed concern that the disposal outlets they currently use may later be deemed unacceptable; this could have severe financial consequences for firms who will then need to find other options.
**Shell:** Disposal of shell can be a big issue for shellfish companies. Processors handling species such as scallop, crab, whelk and nephrops generate large volumes of shell for which they must find outlets. Historically this material presented no problem to the industry, as it could be readily disposed of by a variety of mechanisms including back to the sea. However, the current ABPR requires that shell is classified as Category 3 ABP and is disposed of accordingly. The application of this legislation has required the industry to find new methods of disposal, frequently resulting in significant cost increases. There is a strong view among the shellfish industry that this legislation should not be applicable to shellfish shell.

In order to be utilised in other applications, ABPR requires that shell must be ‘free-of-flesh’ and that this use must be approved by the environmental regulator. However, there is currently no clear definition of what constitutes ‘free-of-flesh’. Seafish are carrying out research to define standards for shell treatment that will enable its re-use in other applications. It is hoped that this work will enable more shellfish processors to find outlets for their shell and potentially derive an income from it.

Some processors have identified outlets where they can sell shell for a range of applications, including as decorative materials for paths and gardens or as aggregate for road surfaces. However, in many instances companies are disposing of shell to landfill or land application at considerable cost.

**The European perspective on shell treatment**

Although ABPR is an EU Regulation, it is implemented to different degrees across Europe. Based on communication between Seafish and other European organisations in the past five years, it is apparent that there are disparities between the UK and other member states.

- There is a significant trade in Europe for whole shellfish, resulting in the waste being generated at the consumer stage.
- There is better infrastructure for the utilisation and/or disposal of seafood by-products in some Member States compared to the UK, meaning that the ABPR presented no real issues or changes.
- There is a wide range of permitted uses for shellfish waste across Europe, with some having no requirement for the shell to be ‘free of flesh’ or to be licensed for use under additional regulatory requirements. This enables the material to be better and more easily utilised through cost-effective routes.
- A small number of Member States have only recently become aware of the requirements of ABPR, and are looking into the range of possibilities for utilisation of seafood waste.
- In a small number of countries, there has been direct Government intervention and funding to assist the seafood industry in developing alternative uses for shellfish waste, particularly in areas with a high dependency on the fish and shellfish sectors.

Clarifying legislative requirements for shell treatment and creating markets for shell produced by UK processors has potential to offer significant benefits to the industry.

### 3.5 Waste minimisation

All companies participating in this project were asked if they had taken measures to reduce seafood waste in their operations.

Most processors were adamant that avoidable fish waste in their operations is minimal, and there is a strong feeling that fish is too valuable a resource to waste. Target yields for filleting are routinely used in finfish operations, and some companies pay staff based on yield obtained to encourage yield maximisation. Target yields vary depending on the species and product format; for example a whole, gutted cod may have a target yield of 50% (45-55%), whereas a headed and gutted cod may have a target yield of 55-60%. Companies will set their own target yields for the species processed and products produced.

Machinery is also used in shell-fish operations and can reduce the quantity of waste produced. For example, machines can be used to extract meat from crab resulting in only very minimal amounts of edible meat being discarded. However, there can be a trade-off in meat quality from use of mechanical rather than manual crab picking.

Table 15 shows the proportion of telephone survey respondents who had taken measures to minimise waste. Although it shows that only a minority of companies have undertaken measures specifically to reduce waste, it is thought likely that there is still a focus on yield optimisation in a majority of firms.
### Table 15: Proportion of companies who have undertaken measures to reduce seafood waste

<table>
<thead>
<tr>
<th>Undertaken measures</th>
<th>All respondents</th>
<th>Primary processors</th>
<th>Secondary Processors</th>
<th>Wholesalers</th>
<th>Fishmongers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30% (82)</td>
<td>30% (41)</td>
<td>40% (29)</td>
<td>26% (16)</td>
<td>13% (4)</td>
</tr>
</tbody>
</table>

The most common measures taken by respondents are shown in Table 16

### Table 16: Measure undertaken to minimise seafood waste

<table>
<thead>
<tr>
<th>Measure undertaken</th>
<th>All respondents</th>
<th>Primary processors</th>
<th>Secondary processors</th>
<th>Wholesalers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff Training</td>
<td>39% (32)</td>
<td>32% (13)</td>
<td>45% (13)</td>
<td>38% (6)</td>
</tr>
<tr>
<td>New machinery/equipment</td>
<td>21% (17)</td>
<td>17% (7)</td>
<td>28% (8)</td>
<td>13% (2)</td>
</tr>
<tr>
<td>Process monitoring</td>
<td>29% (24)</td>
<td>37% (15)</td>
<td>52% (15)</td>
<td>-</td>
</tr>
<tr>
<td>Found new markets for by-products</td>
<td>22% (18)</td>
<td>22% (9)</td>
<td>28% (8)</td>
<td>19% (3)</td>
</tr>
</tbody>
</table>

1) Percentage of companies undertaking waste minimisation measures who utilised this specific approach. Number of companies in brackets

Detailed interviews with companies also highlighted a range of waste minimisation measures that are currently being undertaken. The major cause of waste generation was generally stated as being processing losses, with only extremely minimal waste resulting from factors such as retailer forecasting or cold chain management. The focus of company activities is therefore generally on improvements in processing efficiency.

The following measures were highlighted as having proved effective in waste minimisation:

- **Reducing fish dropped on floor**: Use of catch trays under belts and modifying machinery operation to catch material before it falls on the floor, which would add to the solid material going down the drain.
- **Use of rejected fish**: Fish rejected, e.g. wrong size, can be used in alternative products such as fish cakes.
- **Meat extraction equipment**: Used to extract maximum quantity of meat from crab. Also blowing air through shells to extract residual meat.
- **Sale of fish heads**: Successfully used by some respondents as an income-generating outlet for specific types and sizes of fish heads. A smaller processor commented that this approach is more accessible for larger companies who have significant volumes to export.
- **Targets for yield**: Use of target yields for filleting processes and paying staff based on yield achieved.

The following themes on waste generation and minimisation were also derived from discussion with several respondents:

- **Machinery generated waste**: Mechanised processes (e.g. grading) can result in higher waste than manual operations as machines can lead to increased spillage of product from conveyors.
- **Low waste operations**: Some secondary processor respondents commented that the quantity of waste produced in their operations is minimal and has therefore not required initiatives to reduce.
- **Other waste streams**: Waste derived from some secondary operations such as breading or battering is predominantly not fish waste.
- **Focus on obtaining maximum yield**: Companies are strongly aware of the yield of edible fish which should be obtainable and are focused on ensuring that yields are high.
- **Non-avoidable waste**: A recurring comment from many respondents was that waste generated within their operations is predominantly non-edible portions of fish.

### 3.6 Conclusions on processing waste and co-products

Considerable amounts of waste and co-products are produced by the UK seafood processing industry. However, the majority of this material is derived from non-edible components of fish and is therefore unavoidable.

For finfish processors the most common outlet for non-edible co-products is sale to fishmeal plants, and this represents a valuable source of income to companies. These processors often state that they do not produce fish waste, as all material which is not incorporated into primary products is sold to fishmeal plants as a secondary product.
The situation for shellfish processors is very different. Due to the high volume of non-edible portions of some shellfish and the lack of viable outlets that often exist, waste disposal can be both problematic and expensive. Although some companies have found outlets for shell to be used in other applications, this is not simple to do. Clarifying legislative requirements for shell treatment, and creating markets for shell produced by UK processors, have potential to offer significant benefits to the industry.

Geographic location also has an impact on ease of waste disposal. Companies in remote locations, often traditional seafood landing/processing areas, may find that the nearest ABPR-compliant facility is a considerable distance away, and cost-effective options for waste disposal are simply not available to them. There are also perceived to be regional variations in how the legislation is applied, which may lead to approval of disposal operations being treated differently in different regions.

Initiatives to ensure yields are maximised are relatively common, with processors generally adamant that avoidable waste is insignificant. Discussions within the project indicated that a range of waste minimisation measures have been adopted by companies, generally driven by the need to maximise value from the fish and shellfish processed.
4.0 Waste generation and minimisation within retail

4.1 Retail sector overview
Nielsen provide data for Seafish which monitors the volume and value of retail fish operations based on electronic point of sales data (e.g. from till rolls).22 Table 17 provides a breakdown of both the volumes and values of total sales for 2007-2009.

Table 17: Total volume of UK fish and seafood retail sales (courtesy of Seafish)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh fish</td>
<td>£1514m</td>
<td>137310tpa</td>
<td>£1515m</td>
<td>136472tpa</td>
<td>£1571m</td>
<td>141476tpa</td>
</tr>
<tr>
<td>Frozen fish</td>
<td>£701m</td>
<td>138853tpa</td>
<td>£746m</td>
<td>138005tpa</td>
<td>£763m</td>
<td>134611tpa</td>
</tr>
<tr>
<td>Ambient fish</td>
<td>£422m</td>
<td>114554tpa</td>
<td>£470m</td>
<td>109254tpa</td>
<td>£512m</td>
<td>105249tpa</td>
</tr>
<tr>
<td>Totals</td>
<td>£2638m</td>
<td>385704tpa</td>
<td>£2731m</td>
<td>383348tpa</td>
<td>£2847m</td>
<td>381337tpa</td>
</tr>
</tbody>
</table>

Nielsen data also provides a breakdown of the share of trade for the major UK retailers.22 The percentage share of trade by value for the major retailers in 2009 is shown in Table 18.

Table 18: Multiples share of trade 2009 (courtesy of Seafish)

<table>
<thead>
<tr>
<th>Retailer</th>
<th>Share of trade</th>
<th>Share of trade</th>
<th>Share of trade</th>
<th>Share of trade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All fish</td>
<td>Fresh seafood</td>
<td>Frozen seafood</td>
<td>Shellfish</td>
</tr>
<tr>
<td>Tesco</td>
<td>27.8%</td>
<td>26.8%</td>
<td>27.7%</td>
<td>29.5%</td>
</tr>
<tr>
<td>Sainsbury’s</td>
<td>17.8%</td>
<td>22.2%</td>
<td>13.9%</td>
<td>21.4%</td>
</tr>
<tr>
<td>Asda</td>
<td>13.3%</td>
<td>11.2%</td>
<td>14.0%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Morrisons</td>
<td>12.8%</td>
<td>12.5%</td>
<td>12.5%</td>
<td>10.8%</td>
</tr>
<tr>
<td>Waitrose</td>
<td>5.9%</td>
<td>8.2%</td>
<td>3.7%</td>
<td>4.6%</td>
</tr>
<tr>
<td>Somerfield</td>
<td>3.2%</td>
<td>3.2%</td>
<td>3.0%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Iceland</td>
<td>4.8%</td>
<td>0.0%</td>
<td>11.8%</td>
<td>6.4%</td>
</tr>
<tr>
<td>Co-Op</td>
<td>2.2%</td>
<td>2.7%</td>
<td>1.6%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Marks &amp; Spencer</td>
<td>5.2%</td>
<td>10.3%</td>
<td>1.3%</td>
<td>4.3%</td>
</tr>
</tbody>
</table>

The vast majority, approx. 80%, of seafood in the UK is sold through supermarkets. There is, however, still a strong independent fishmongers sector that is responsible for about 12% of the total seafood market. This sector had a market value of £236m in 2005, and there are in excess of 600 individual fishmonger businesses within the UK.23

Discussions were held with six of the major multiples; Sainsbury’s, Tesco, Asda, Marks & Spencer, Morrisons and the Co-operative (now including Somerfield). Together these companies comprise approximately 80% of UK supermarkets fish retail.24 Thirty fishmongers also participated in the project telephone survey.

4.2 Retail waste arisings

4.2.1 Waste from multiples
A 2010 study carried out for WRAP on waste in food and drink supply chains found that a total of 1.4mt of waste is produced annually in the retail sector, comprising approximately 8% of all waste generated throughout the supply chain.25 Of this, the majority of the waste (7.6%) was generated in retail, with only a very minor quantity (0.5%) produced in distribution. The study provided figures for estimated retail waste arising in 2008 of 361,800tpa food waste and of 1046,400 tpa packaging. Of the food waste, 129,600 tpa was recovered, with the remaining 232,000tpa sent to landfill or other disposal methods.

The report categorised waste disposed of food type, based on studies carried out by retailers on back-of-store waste. By extrapolating this figure across the whole retail sector, an estimate of 23,700t of fish waste was derived for retail in 2008. If this figure is used in conjunction with the figure from the Nielsen data on total retail volumes, this equates to an overall wastage in retail of approximately 6% by volume.

It is reasonable to assume that the majority of waste collected will be fresh fish, as disposal of frozen and ambient products would be expected to be minimal due to the long shelf life of these products.
All six of the multiples participating in this work were asked to provide figures for the quantities of fish waste produced annually. However, this figure was not readily obtainable. Retailers monitor sales by line and obtain data on un-sold products, which are a financial loss and therefore constitute waste to the retailer. These products are frequently then sold through mark-downs or as discount sales to staff, and therefore do not represent final waste for disposal. Fish waste from stores is also frequently combined with meat waste for disposal, so accurate figures on quantities of waste for final disposal were also unavailable.

The following key pieces of information on waste quantities were obtained from the six participating multiples:

- Figures between 3-8% waste were quoted for fresh fish.
- For the 2 respondents who quoted a figure of 3%, it is notable that in one instance this figure was quoted as a ‘target for mark downs’ rather than an actual number achieved.
- The higher figures provided by retailers (6-8%) were those which appeared to be based on the most complete data set.
- Figures for waste of frozen fish were quoted as 0.5-1.5%.

The estimates for retail waste arisings quoted in the resource maps are based on the assumptions that: a) Waste arising from fresh fish retail is 5%; and b) waste arising from frozen and ambient retail is 1%. It must be highlighted that these quoted figures will differ from final figures of waste disposal for two key reasons:

- a significant amount of this material may subsequently be sold either via mark down or to staff; and
- these figures do not take account of waste from processing on fish counters.

Of the six respondents, four have fish counters in a significant number of stores. One respondent noted that the main cause of fish waste in their stores would be non-avoidable waste derived from processing operations by in-store fishmongers. Although in many cases in-store processing may be low, this will contribute to the waste generated by retailers.

The two reasons highlighted above will at least partially account for the difference in retail waste arising figures derived from this study, and the slightly higher figure that can be derived from the previous WRAP study.

**Variation in waste by species**

Although figures on waste generation by species were not obtained in most instances, several respondents commented on the following factors that may influence waste on a species-specific basis:

- Species with high volume of sales will give rise to lower waste levels: salmon, prawns, cod, haddock and tuna were quoted by one retailer as the most significant species in terms of sales volumes, and estimated waste levels for these species as <1%.
- Lower volume or higher value products may be associated with higher waste levels.
- Tuna may suffer from ‘browning’ while still in date. This can result in products being rejected by consumers.

### 4.2.2 Depot waste

Retailers were also asked about the quantity of waste that may be produced in depots due to product rejection, and what the causes of rejection are.

The following reasons for rejection of products were provided:

- product damage, including damage to packaging;
- product outside specification or poor quality;
- product incorrectly labelled; and
- temperature rejection based on checking lorry and product temperature

All respondents commented that waste arising in depots was low. However, only two companies were able to quantify this, both of whom provided an overall figure for depot rejects of 0.5%. The low levels of rejection observed were often attributed to good established relationships with suppliers. Product that is rejected at depots is taken back by the supplier and may be repackaged and sold through other outlets or donated to charities. However, the short shelf life of fresh fish may limit the effectiveness of these mechanisms.

### 4.2.3 Waste from fishmongers

Of the 30 fishmongers who participated in the telephone survey, 16 were able to provide figures for both the quantity of raw material which they purchase and the quantity of waste generated. The size of these operations ranged from those who purchased only 1-2 tonnes of fish a year to larger operations purchasing up to 1,000 tonnes of fish a year. In many instances fishmongers will purchase whole or gutted fish, and will carry out some
processing on site, so it is expected that the wastes derived in their operations would be proportionately higher than from multiple retailers. The most common reason cited by fishmongers for waste arisings was processing operations.

No obvious trend in quantities of waste generated was observed from the survey participants, with responses varying from extremely low levels (five respondents quoted <5% waste) to extremely high (one response of 83% and another of 100%). It is therefore impossible to derive an average figure from this dataset or to extrapolate across the fishmonger community as a whole. It was, however, apparent from some of these responses that some fishmongers do not have a clear idea of the quantities of waste which they generate annually.

Based on these responses it has not proved possible to produce an estimate of fishmongers’ waste for inclusion in the resource maps.

4.3 Waste minimisation mechanisms

4.3.1 Multiples

All of the multiple retailers who participated in this work emphasised that they adopt a range of measures to reduce waste within their operations.

Approaches that were common to most retailers include the following:

- Use of mark downs to sell products close to sell by dates; one retailer commented that mark downs on fish need to be higher than for other food types due to customer concerns about fish not being fresh.
- Shelf-stacking to maximise shelf life; slanting shelves minimises high stacking and improves air flow around products.
- Control of stock ordering/forecasting.
- Monitoring storage temperatures in refrigeration units.

One respondent commented that fish generally have consistent ordering cycles, as demand is quite stable. Fish sales are not unduly influenced by factors such as weather, which makes accurate forecasting relatively easy.

Additional mechanisms that were used by several retailers include:

- Modifying packaging to enhance shelf life. May include variations in modified atmosphere or use of vacuum packaging.
- Reducing occurrence of gas leakages in packaging.
- Selling ‘close to sell by date’ products to staff at large discount.

Several respondents also mentioned that they donate waste food to charities such as FareShare. However, this was not generally a major outlet for fish due to the short shelf life of fresh products.

The majority of suppliers to the multiple retailers are large seafood processing companies, and in most cases the retailers have established long-term relationships with these suppliers. Several retailers commented that they work with suppliers to minimise waste. Mechanisms used included encouraging lean manufacturing and also joint initiatives to reduce packaging weights.

4.3.2 Fishmongers

Of the 30 fishmonger survey respondents, only four stated that they had taken measures to minimise seafood waste produced by their operations. By contrast 11 had looked at minimising packaging waste.

Measures taken to minimise waste included staff training and use of new equipment. Only four of the fishmongers interviewed stated that waste disposal was a problem for them, with the most common reason being the cost of disposal (two respondents).

4.4 Waste disposal and co-product utilisation

4.4.1 Utilisation and disposal mechanisms – multiples

ABPR prohibits the disposal of uncooked or untreated fish products to landfill, and retailers have therefore had to adopt methods which are ABPR-compliant. The major outlet for the retail sector is rendering, and retailers frequently mix fish and meat waste together before it is sent to the renderer. Rendering was used to some extent
by all multiples that specified an outlet, and by some was the sole method used. Rendering will generate protein meal and an oil component both of which may be used in a range of applications. Due to the impact of ABPR, use of protein meal in animal feeds is a less common outlet and one of the main uses of this material is incineration as a fuel.\textsuperscript{20}

Other outlets quoted as significant are manufacture of pet food and use for maggot breeding at fish farms. One respondent stated that due to the high quality of material, they were looking to significantly increase the quantity of material used in pet food manufacture from 30 to 60%. A second respondent commented that they were interested in the possibility of then being able to sell pet food products derived from this as ‘pet treats’ in-store.

Final disposal volumes will contain some packaging. Where possible, retailers separate packaging from food. However, as contaminated packaging must be treated in compliance with ABPR, contact packaging is frequently disposed of by the same method as the fish. Some retailers commented that the rendering process could cope with small amounts of packaging. However, it is known that renderers have had to upgrade their processes in recent years in order to deal with packaging. Other big retailers stated that contaminated packaging was disposed of separately, generally by incineration.

\subsection{4.4.2 Waste disposal mechanisms – fishmongers}
A range of utilisation and disposal methods were cited by fishmongers with the most common including landfill, incineration, fishmeal, and use as bait. A considerable number of respondents also stated that ‘other methods’ were used, although no further information was collected on what these methods were. Costs per tonne for waste disposal were generally not available, although many respondents quoted a figure of zero for bait indicating that this may be a cost-neutral means of utilisation, which is therefore quite frequently used by fishmongers.

\section{4.5 Conclusions: retail waste generation}
Quantifying the waste generated within UK seafood retail operations is not simple. There are many fishmongers in the UK, and no clear trends in waste arisings can be derived from the sub-set of approximately 5% who provided data to this study. This may be due to the highly diverse nature of operations, but is also driven by a lack of available information on waste quantities.

Accurate data on waste disposed of by the multiple retailers is also not readily available, although indicative figures on levels of products considered as ‘commercial wastes’ to retailers have been obtained. The average figures obtained in this study indicate waste levels of approximately 5% for fresh products and <1% for ambient or frozen products. However, these figures exclude any wastes from processing on fish counters and, in some instances, include a level of estimation by retailers. Comparison of this figure with the figure of 6%, which can be derived from the previous WRAP study\textsuperscript{25}, indicates that the total figure for fish waste generated within the retail sector may be slightly higher than estimated using the current figures.

A range of outlets is used by multiple retailers to dispose of or utilise this material. Rendering appears the most common outlet with fish and meat wastes often being combined.

Finally, the survey did highlight the considerable focus on minimising waste among all the multiple retailers interviewed, with a variety of mechanisms being adopted.
5.0 Packaging usage in seafood supply chains

5.1 Introduction
The use of packaging in seafood supply chains is subject to legislation in the form of EC Directive 94/62/EC (and the amending Directive 2004/12/EC), known as the Packaging Directive. It aims to minimise the negative effects of packaging waste on the environment, and, by providing a single legislative format throughout the EU, to prevent individual member states’ packaging legislation creating barriers to trade. The directive requires that at least 60% by weight of packaging from each member state must be recovered or incinerated with energy recovery. It also includes minimum recycling targets for specified materials: 60% for paper and cardboard, 50% for steel, 50% for aluminium, 60% for glass and 22.5% for plastics. In the UK this directive has been implemented in the form of two regulations.

- The Packaging (Essential Requirements) Regulations.

The Producer Responsibility Obligations stipulate the minimum levels of packaging to be recovered annually, and applies to packaging producers who handle more than 50 tonnes a year of packaging and have a turnover of more than £2 million. In the scope of this project, these regulations will apply to both larger seafood processors who package products, and also to the multiple retailers who sell packaging to the final consumer. These companies have to meet targets for recovery and recycling of packaging, where the targets are based on the quantity of packaging handled, annual recovery and recycling targets and the type of activity performed by the business. However, these regulations are currently not applicable to many small and medium sized seafood processors whose turnover is below the threshold level.

The Packaging (Essential Requirements) Regulations are concerned with minimising the environmental impact of packaging. They require that the minimum amount of packaging sufficient to meet product protection requirements is used, that packaging does not exceed stated levels of heavy metals or other hazardous substances, and that the packaging can be reused or recovered.

A wide range of packaging materials is used at various stages throughout seafood supply chains. Many packaging material decisions are driven by the short shelf life of fresh fish products, and the need to prevent product deterioration. For example, thermal insulation is a property of high importance for transit packaging of fresh fish, and has traditionally led to expanded polystyrene (EPS) being the material of choice for this application. Likewise, primary packaging with a modified environment is also used to maintain product freshness.

Table 19 summarises the major types of packaging used at various stages of seafood supply chains.

5.2 Approach to data collection within current project
Companies participating in either the detailed interviews or the telephone survey were asked a series of questions about their packaging usage.

Key questions addressed the following areas:
- What type of packaging do seafood raw materials arrive in?
- What two types of packaging do you have the most to dispose of and in what quantities?
- How do you dispose of this packaging?
- What type of primary packaging do you use for products?
- What type of secondary and transit packaging do you send your products out in?
- What measures have you taken to minimise packaging waste?

Companies participating in detailed interviews, including the six multiple retailers, were also asked more involved questions about approaches taken to minimise packaging waste throughout the supply chain, and to move disposal approaches up the waste hierarchy.
Table 19: Packaging used throughout supply chain

<table>
<thead>
<tr>
<th></th>
<th>EPS boxes</th>
<th>Cardboard boxes (inc. waxed)</th>
<th>Plastic trays</th>
<th>Plastic bags</th>
<th>Plastic liners &amp; strapping</th>
<th>Ice/gel packs</th>
<th>Wooden pallets (transit)</th>
<th>Plastic shrink-wrap (transit)</th>
<th>Plastic re-useable pallets (transit)</th>
<th>Re-useable plastic boxes (&lt;70l)</th>
<th>Re-useable plastic tubs (&lt;600l)</th>
<th>Foil bags</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imports (chilled)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Imports (frozen)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK landings (chilled)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>UK landings (frozen)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processors &amp; wholesaler</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Retail (transport packaging on material received)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
5.3 Packaging usage

5.3.1 Transit packaging for raw materials

Telephone survey participants were asked about the type of packaging that is used to transport fish to their site. Respondents were asked to identify all types of packaging they routinely used and the percentage responses given for the most common types of packaging are shown in Table 20. The number of respondents is given in brackets.

<table>
<thead>
<tr>
<th>Type of packaging</th>
<th>Primary processors</th>
<th>Secondary processors</th>
<th>Wholesalers</th>
<th>Fishmongers</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPS fish boxes</td>
<td>30% (41)</td>
<td>46% (33)</td>
<td>46% (28)</td>
<td>60% (18)</td>
</tr>
<tr>
<td>Cardboard boxes</td>
<td>16% (21)</td>
<td>44% (32)</td>
<td>28% (17)</td>
<td>40% (12)</td>
</tr>
<tr>
<td>Plastic shrink-wrap</td>
<td>14% (19)</td>
<td>21% (32)</td>
<td>8% (5)</td>
<td>3% (1)</td>
</tr>
<tr>
<td>Plastic boxes or tubs</td>
<td>80% (108)</td>
<td>54% (39)</td>
<td>64% (39)</td>
<td>53% (16)</td>
</tr>
<tr>
<td>Ice/gel packs</td>
<td>10% (13)</td>
<td>11% (8)</td>
<td>5% (3)</td>
<td>13% (4)</td>
</tr>
<tr>
<td>Plastic bags</td>
<td>9% (12)</td>
<td>14% (10)</td>
<td>8% (5)</td>
<td>20% (6)</td>
</tr>
<tr>
<td>Wooden pallets</td>
<td>23% (31)</td>
<td>32% (23)</td>
<td>26% (16)</td>
<td>7% (2)</td>
</tr>
</tbody>
</table>

Survey participants were then asked to identify the two types of packaging which were the cause of the most significant amount of waste on their sites. The responses to this question are shown in Table 21. Responses to this question showed very clearly that there are three types of packaging that comprise the most significant amount of waste arisings at all stages of the supply chain of interest to the current project:

- EPS fish boxes;
- cardboard boxes; and
- plastic boxes or tubs.

<table>
<thead>
<tr>
<th>Type of packaging</th>
<th>Primary processors</th>
<th>Secondary processors</th>
<th>Wholesalers</th>
<th>Fishmongers</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPS fish boxes</td>
<td>30% (40)</td>
<td>43% (31)</td>
<td>44% (27)</td>
<td>53% (16)</td>
</tr>
<tr>
<td>Cardboard boxes</td>
<td>10% (13)</td>
<td>33% (24)</td>
<td>20% (12)</td>
<td>30% (9)</td>
</tr>
<tr>
<td>Plastic shrink-wrap</td>
<td>3% (8)</td>
<td>4% (6)</td>
<td>2% (1)</td>
<td>3% (2)</td>
</tr>
<tr>
<td>Plastic boxes or tubs</td>
<td>64% (86)</td>
<td>35% (25)</td>
<td>51% (31)</td>
<td>30% (9)</td>
</tr>
<tr>
<td>Ice/gel packs</td>
<td>1% (3)</td>
<td>1% (1)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Plastic bags</td>
<td>4% (6)</td>
<td>4% (3)</td>
<td>3% (2)</td>
<td>7% (2)</td>
</tr>
<tr>
<td>Wooden pallets</td>
<td>6% (15)</td>
<td>6% (8)</td>
<td>5% (3)</td>
<td>3% (1)</td>
</tr>
</tbody>
</table>

Participants were asked to quantify the amounts of each material they have to dispose of annually. However, this question was poorly answered with approximately 50% of respondents stating that they did not know quantities.

The following analysis of data focuses on these three most significant types of packaging waste: EPS, cardboard and plastic boxes or tubs.

5.3.2 Disposal and recovery mechanisms for transit packaging

For the two most significant types of packaging waste specified, companies were asked what types of disposal or recovery method they used. The most common methods used for the three most significant types of packaging waste are given below in Tables 22-24. Companies were asked to select all mechanisms used, so figures provided in these tables are percentages of companies who used this mechanism, rather than percentage material disposed of by this mechanism.
**Table 22**: Outlets for EPS fish boxes

<table>
<thead>
<tr>
<th></th>
<th>Primary processors</th>
<th>Secondary processors</th>
<th>Wholesalers</th>
<th>Fishmongers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfilled</td>
<td>15% (6)</td>
<td>29% (9)</td>
<td>33% (9)</td>
<td>13% (2)</td>
</tr>
<tr>
<td>Compacted on site</td>
<td>30% (12)</td>
<td>32% (10)</td>
<td>15% (4)</td>
<td>-</td>
</tr>
<tr>
<td>then recycled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recycled</td>
<td>40% (16)</td>
<td>42% (13)</td>
<td>26% (7)</td>
<td>38% (6)</td>
</tr>
<tr>
<td>Re-used on site</td>
<td>23% (9)</td>
<td>16% (5)</td>
<td>26% (7)</td>
<td>31% (5)</td>
</tr>
</tbody>
</table>

**Figure 36**: Outlets used for expanded polystyrene

**Table 23**: Outlets for cardboard boxes

<table>
<thead>
<tr>
<th></th>
<th>Primary processors</th>
<th>Secondary processors</th>
<th>Wholesalers</th>
<th>Fishmongers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfilled</td>
<td>31% (4)</td>
<td>21% (5)</td>
<td>25% (3)</td>
<td>11% (1)</td>
</tr>
<tr>
<td>Compacted on site</td>
<td>23% (3)</td>
<td>21% (5)</td>
<td>8% (1)</td>
<td>-</td>
</tr>
<tr>
<td>then recycled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recycled</td>
<td>54% (7)</td>
<td>58% (14)</td>
<td>42% (5)</td>
<td>78% (7)</td>
</tr>
<tr>
<td>Collected by local</td>
<td>8% (1)</td>
<td>4% (1)</td>
<td>25% (3)</td>
<td>11% (1)</td>
</tr>
<tr>
<td>council</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 37**: Outlets used for cardboard boxes
Although the results shown in Tables 22-24 and Figures 36-38 cannot be used to provide an estimate of the amounts of material utilised or disposed of by each mechanism, they do provide a view as to the most common approaches. For all three types of packaging it is reasonable to assume that the majority of material is recycled or re-used rather than disposed of to landfill. The prevalence of recycling and reuse is particularly noticeable for plastic boxes and tubs.

Noticeable amounts of polystyrene and cardboard are still disposed of to landfill, and this may be due to a number of reasons, namely:

- The high volume and low weight of EPS can mean that it is not cost-effective to transport it long distances for recycling.
- Compactors for EPS are only cost-effective for companies who generate significant quantities (data shows significantly higher use of compactors by larger companies, reflecting the higher volumes of EPS these companies will generate).
- The recyclability of both EPS and cardboard can be reduced by contamination from fish products.
- Heavily contaminated packaging must be disposed of in compliance with ABPR.

### 5.3.3 Transit packaging materials for products

Respondents were also asked to identify the types of secondary packaging they used to transport their products. This material will generally result in only minimal waste at the respondents’ site, for example small amounts of damaged packaging, but may result in considerable waste arisings further up the supply chain. Table 25 summarises the main types of materials used.

By far the most significant types of secondary packaging used by all respondent types are polystyrene and cardboard boxes. The use of plastic boxes and tubs is far less prevalent than as transit packaging for raw materials (see Table 20). This indicates that, as anticipated by the overview shown in Table 19, this type of packaging is predominantly used to transport fish direct from landings.

---

**Table 24: Outlets for plastic boxes or tubs**

<table>
<thead>
<tr>
<th></th>
<th>Primary processors</th>
<th>Secondary processors</th>
<th>Wholesalers</th>
<th>Fishmongers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfilled</td>
<td>3% (3)</td>
<td>1% (4)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Reused on site</td>
<td>59% (51)</td>
<td>68% (17)</td>
<td>52% (16)</td>
<td>67% (6)</td>
</tr>
<tr>
<td>Recycled</td>
<td>34% (29)</td>
<td>32% (8)</td>
<td>45% (14)</td>
<td>22% (2)</td>
</tr>
<tr>
<td>Returned to fishermen/boats</td>
<td>10% (9)</td>
<td>8% (2)</td>
<td>16% (5)</td>
<td>11% (1)</td>
</tr>
</tbody>
</table>

**Figure 38: Summary of outlets for plastic boxes or tubs (all respondents)**
Table 25: Percentage of companies using specific types of secondary packaging for products

<table>
<thead>
<tr>
<th>Type of packaging</th>
<th>Primary processors</th>
<th>Secondary processors</th>
<th>Wholesalers</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPS fish boxes</td>
<td>49% (66)</td>
<td>40% (29)</td>
<td>48% (29)</td>
</tr>
<tr>
<td>Cardboard boxes</td>
<td>41% (56)</td>
<td>50% (36)</td>
<td>30% (18)</td>
</tr>
<tr>
<td>Plastic shrink-wrap</td>
<td>21% (29)</td>
<td>22% (16)</td>
<td>15% (9)</td>
</tr>
<tr>
<td>Plastic boxes or tubs</td>
<td>8% (11)</td>
<td>13% (9)</td>
<td>13% (8)</td>
</tr>
<tr>
<td>Ice/gel packs</td>
<td>11% (15)</td>
<td>6% (4)</td>
<td>11% (7)</td>
</tr>
<tr>
<td>Plastic bags</td>
<td>17% (23)</td>
<td>22% (16)</td>
<td>13% (8)</td>
</tr>
<tr>
<td>Wooden pallets</td>
<td>29% (39)</td>
<td>33% (24)</td>
<td>20% (12)</td>
</tr>
</tbody>
</table>

5.3.4 Primary packaging materials
Companies were also asked about the type of primary packaging used to send products out. This packaging will generally result in waste generation further up the supply chain with consumers. Respondents’ utilisation of the most common types of materials is summarised in Table 26. Companies could provide multiple answers to identify all major types of packaging used. This table shows the wide range of primary packaging products in use by the industry. The majority of this packaging will result in either household waste to be disposed of by consumers or waste within foodservice.

Table 26: Most common types of primary packaging for products

<table>
<thead>
<tr>
<th></th>
<th>Primary processors</th>
<th>Secondary processors</th>
<th>Wholesalers</th>
<th>Fishmongers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic trays</td>
<td>30% (41)</td>
<td>42% (30)</td>
<td>26% (16)</td>
<td>23% (7)</td>
</tr>
<tr>
<td>Cardboard boxes</td>
<td>36% (49)</td>
<td>47% (34)</td>
<td>26% (16)</td>
<td>10% (3)</td>
</tr>
<tr>
<td>Waxed or lined</td>
<td>27% (33)</td>
<td>33% (24)</td>
<td>28% (17)</td>
<td>10% (3)</td>
</tr>
<tr>
<td>Plastic film</td>
<td>30% (40)</td>
<td>33% (24)</td>
<td>28% (17)</td>
<td>13% (4)</td>
</tr>
<tr>
<td>Plastic bags</td>
<td>42% (57)</td>
<td>54% (39)</td>
<td>34% (21)</td>
<td>73% (22)</td>
</tr>
<tr>
<td>Plastic pouches</td>
<td>14% (19)</td>
<td>24% (17)</td>
<td>15% (9)</td>
<td>10% (3)</td>
</tr>
<tr>
<td>Polystyrene boxes</td>
<td>24% (33)</td>
<td>10% (7)</td>
<td>34% (21)</td>
<td>7% (2)</td>
</tr>
</tbody>
</table>

5.3.5 Packaging waste minimisation
All companies were asked if they had taken measures to reduce the quantity of packaging waste produced at their site. Table 27 summarises the responses obtained from both telephone survey and detailed interview respondents. This shows that a relatively high proportion of processors and all of the big retailers have actively looked at measures to minimise packaging waste.

Among the detailed interview responses, several stated that they had not looked at minimising packaging waste, as they had only very minimal packaging waste on site and that this did not constitute a problem or significant cost to the company.

Table 27: Breakdown of companies who have adopted measures to minimise packaging waste

<table>
<thead>
<tr>
<th></th>
<th>Primary processors</th>
<th>Secondary processors</th>
<th>Wholesalers</th>
<th>Fishmongers</th>
<th>Multiple retailers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telephone survey</td>
<td>45% (61)</td>
<td>63% (45)</td>
<td>39% (24)</td>
<td>37% (11)</td>
<td>-</td>
</tr>
<tr>
<td>Detailed data</td>
<td>57% (7)</td>
<td>50% (4)</td>
<td>100% (1)</td>
<td>-</td>
<td>100% (6)</td>
</tr>
</tbody>
</table>

Table 28 shows the breakdown of responses across all telephone survey respondents based on company size. There is a notable trend that larger companies are more likely to have undertaken waste minimisation measures and, although detailed data respondents are not specifically included in this data, these interviews support this trend.
### Table 28: Breakdown by size of companies who have adopted measures to minimise packaging waste

<table>
<thead>
<tr>
<th></th>
<th>&lt;10 employees</th>
<th>10-49 employees</th>
<th>50-99 employees</th>
<th>100-499 employees</th>
<th>&gt;500 employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telephone survey respondents who have adopted measures to minimise packaging waste</td>
<td>36% (45)</td>
<td>51% (53)</td>
<td>69% (18)</td>
<td>69% (9)</td>
<td>100% (2)</td>
</tr>
</tbody>
</table>

Many of the big retailers stated that they work with their suppliers on initiatives to reduce packaging, either by light-weighting or by increasing recycled content. As the majority of supplies to the multiple retailers are larger processors, this may explain some of their increased focus on packaging waste reduction.

Within the detailed data collection work, more involved questions were asked about changes to packaging adopted by processors. Some of the small companies stated that they were independently looking at reducing the weight or increasing recyclability of packaging. In some instances this was driven by cost benefits resulting from using lower quantities of packaging. For one processor who sold direct to small retailers and foodservice, the motivation was developing a product image for ‘local and sustainable’ produce.

#### 5.3.6 Packaging case studies: waste minimisation and more sustainable disposal methods

A wide range of approaches has been adopted at various stages throughout seafood supply chains to move towards more sustainable approaches to packaging use.

**Retailers**

Reduction of packaging weights and increased recycled content are a key focus for all the major retailers, many of whom are signatories to the Courtauld Commitment, and are working towards demanding targets to enhance the sustainability of packaging. Several examples of initiatives undertaken relating to fish products are illustrated by the following:

**Retailer Case Studies**

**Marks & Spencer**: M&S is planning to move away from using EPS fish boxes for transport of fish and, in future, intends all transport packaging to involve the use of polyethylene boxes. These boxes contain some recycled content and are fully recyclable. In the event of damage to boxes they can be ground down and re-made into new boxes. This approach will result in zero waste from transporting these products.

**Sainsbury’s**: Use of trays with flow wrap for packaging of salmon fillets has resulted in a weight reduction of approx 20%. This has resulted in an annual saving of packaging usage of 57 tonnes of plastic. This new packaging should also potentially have a better seal which may further reduce waste. Ironically, customers’ perception of the new product is that it contains more rather than less packaging although this does not appear to have had a negative impact on sales.

Sainsbury’s have also moved to use of recycled PET for all fresh prawn trays. This material is recyclable after use and is saving 205 tonnes of virgin plastic a year.

**Tesco**: Has investigated approaches to reduce the quantity of packaging by 25%. This approach has been applied to smoked salmon, which was previously sold in a plastic pouch and cardboard sleeve. By replacing the cardboard sleeve with printed plastic film they have achieved a weight reduction of 25%; however, the new version is not fully recyclable.

Several big retailers commented that they have reduced the quantity of EPS used in transit packaging due to concerns about recyclability. Although EPS can be readily compacted and recycled, this is only cost effective on a relatively large scale, which may not be applicable for individual supermarkets. Likewise the use of light-weighted trays appears to be an area of considerable interest to retailers. One approach includes the use of dimpled bases to collect juice, which removes the requirement for an absorbent pad. One respondent commented that there is a limit to the extent to which packaging can be light-weighted, as excessive light-weighting can result in insufficient modified environment within the packaging to maintain product freshness.
Increasing recycled content in packaging is also a key focus for many retailers. However, there is currently a physical limit to the proportion of recycled content that can be included and some virgin material is required to enhance the strength of packaging.

**Processors**

There are many examples of initiatives undertaken by processors to reduce their packaging usage or increase recycled content. Some simple case studies of work that has been undertaken are highlighted below:

**Processor Case Studies**

*Lightweighting of scallop packaging:* A scallop processor provided information on approaches being undertaken to reduce the quantity of packaging used for their products. They have adopted an approach of using thinner and lighter materials, and have achieved a reduction in the thickness of plastic used by 52% over the last three years.

*Lightweighting of packaging for value-added products:* A small secondary processor, whose current product range is sold in glass or plastic jars, is investigating a change to use plastic pouches as primary packaging for products. This has potential to deliver a significant saving in the quantity of packaging used. A key motivation for this processor was enhancing their sustainability credentials to help build a brand reputation for sustainable, local produce.

One of the large processors participating in this work outlined the measures that they are looking at as part of a major drive to improve packaging. Approaches included increased use of recycled content, use of dimples to collect drips that remove the need for absorbent pads, reduced thickness of packaging materials for weight reduction and the use of smaller labels. As a major supplier to several of the big multiples, this company's initiatives are very much in line with those described above for retailers.

**Wholesale**

**Wholesale Case Study**

*Billingsgate wholesale market:* Billingsgate is one of the UK’s largest wholesale markets and participated in the detailed data collection work in this project. This wholesale market incorporates trading establishments for over 50 separate merchants resulting in sales of approximately 25,000 tonnes of fish a year. Considerable amounts of packaging waste are generated on this site, and the market has adopted a very proactive approach to deal with this issue. The major types of waste the market deals with are wooden pallets, EPS fish boxes and cardboard. The market has installed compactors to melt and compress EPS to form blocks, which are then sent to China for inclusion into recycled products. Cardboard waste is also baled on site and sent for recycling. Finally, wood pallets are chipped and sent for recycling. By adopting these measures for segregation and recycling of waste streams, Billingsgate market has reduced the number of collections for waste sent to landfill from six to two a week.

5.4 **Conclusions: packaging use**

A wide range of initiatives is underway at all stages in the UK seafood supply chain to minimise the impact of packaging. These initiatives encompass all aspects of the waste hierarchy, from minimising the quantity of packaging used to diverting waste from landfill.

Many initiatives are driven by retailers looking to meet demanding targets under the Courtauld Commitment, and to address consumer concerns about excessive packaging. Due to the strong relationship the big multiples have with their key suppliers, this can lead to the adoption of waste reduction mechanisms throughout the supply chain.

Additionally, there are examples of packaging reduction work undertaken independently by small processors. These companies are often driven by the incentive of reducing costs associated with both the purchase and disposal of packaging. Where processing companies are situated close to landing sites of fish, the re-use of transit packaging, either by return to fishermen or re-use for other purposes on the harbour, has long been common practice.
There are, however, some packaging issues which continue to present a challenge to the seafood industry. Disposal of contaminated packaging can cause issues, as this material cannot always be readily recycled. Heavily contaminated packaging should be treated in accordance with ABPR, and, as has been noted, this is often not straightforward.

Another key issue, which is still being addressed by the industry, is the waste arising from transit packaging. Expanded polystyrene (EPS) has traditionally been the material of choice for fish boxes due to the light weight and high thermal insulation properties of the material. However, EPS has acquired a bad environmental reputation and moves to alternative materials are being investigated. Several of the big retailers were keen to stress that they are reducing the quantity of EPS which they use for transport of fish. It is, however, important to consider a range of factors when identifying the best choice of transit packaging. Trials by Seafish have shown EPS to have improved thermal insulation properties by comparison to some of the more common alternative materials. The low weight of EPS may also minimise its environmental impact for use in transport. Recycling of EPS through use of compactors is increasingly being adopted where possible within seafood supply chains, for example by wholesale markets and docks. However, a significant volume of EPS is needed to make these approaches cost effective, and compactors are therefore unlikely to provide a solution for individual smaller-sized processors. Further clarification is therefore needed to identify the best materials for use as thermally insulating transit packaging within seafood supply chains.
6.0 Water usage within seafood processing

6.1 Industry water usage: background and legislation
The seafood processing industry involves many water-intensive processes. Fundamental operations, such as thawing, washing and filleting, all require water, and in many instances traditional industry processes result in considerable water wastage.

Historically fish processors regarded water as a cheap and readily available resource and often disposed of effluent by direct discharge to the sea. However, legislation has changed this situation, and required companies to re-think their approach to water management in order to comply with legislation and remain economically viable. For example, the EU Urban Waste Water Treatment Directive (UWWTDD) implemented in 2000 imposed the requirement for urban waste water (including mixed domestic and industrial effluent) to be treated before discharge.

UK legislation requires that trade effluent is discharged either to a local sewer or by direct discharge to local waters. Consent for direct discharge is generally only given for open sea discharge, and usually requires that the effluent has undergone primary treatment. The majority of effluent is therefore sent to public sewers. This is subject to consent by the water company who will impose limitations on the strength and quantity of discharge permitted.

The IPPC (Integrated Pollution Prevention and Control) system is designed to control the environmental impact of industrial activities and controls emissions to air, land and water. The food and drink industry is covered by these regulations. Since September 2005, facilities that process animal raw materials and have a finished product capacity greater than 75 tonnes a day have been required to have an IPPC permit. To gain a permit, companies must show that they are applying best available techniques (BAT) for pollution prevention and control.

Food Safety Regulations also apply constraints on the seafood industry, as they dictate that all water used, except that used for non-food applications such as steam production, must be ‘clean’ which is considered to be of drinking water standards. Seafood processors generally pay for use of mains water and for disposal and treatment of the effluent produced. Minimising water usage, therefore, has the potential to reduce the costs of both.

Guidance previously produced by Seafish highlights areas where water use and effluent strength could be reduced, and suggests a range of low cost measures to deliver these improvements. This work by Seafish was carried out over ten years ago, and an objective of the current work was to understand the extent to which the measures suggested have been adopted by the industry.

Initiatives such as the Federation House Commitment (FHC) and Rippleffect, both managed by WRAP, provide a means to help companies to reduce their water use. The FHC is a responsibility deal established to help the food and drink sector reduce its water use by 20% by 2020. Signatories can receive a package of free support to help them to understand and minimise their water usage and potentially realise considerable savings in water bills. The Rippleffect, is an on-line training package which helps manufacturers to identify and measure water use and to take steps to manage it. It is, unlikely that the majority of small and medium seafood processing companies will be aware of these initiative or have taken advantage of the potential help which they offer.

6.2 Existing data on water usage
Previous work carried out by Seafish has involved detailed water audits of a small selection of seafood processors to identify water usage for standard operations. Results of this previous work are shown in Table 29.

<table>
<thead>
<tr>
<th>Type of Operations</th>
<th>Number of companies audited</th>
<th>Water usage to produce 1 tonne of product (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White fish filleting</td>
<td>3</td>
<td>5.0-7.4</td>
</tr>
<tr>
<td>White fish thawing and filleting</td>
<td>3</td>
<td>9.5-24.0</td>
</tr>
<tr>
<td>White fish thawing, filleting, enrobing &amp; freezing</td>
<td>1</td>
<td>23.4</td>
</tr>
<tr>
<td>Pelagic primary processing</td>
<td>2</td>
<td>3.2-6.6</td>
</tr>
<tr>
<td>Nephrops primary and secondary processing</td>
<td>1</td>
<td>38.7</td>
</tr>
</tbody>
</table>
Additional work carried out by the United Nations Environment Programme (UNEP) provides figures for water usage expected in filleting processes, using both standard techniques and BAT (Table 30). This work also contains indicative figures for water use for processing of some species of interest to the current project (Table 31).^{34}

### Table 30: Water usage for filleting processes (based on 1000kg frozen fish)^{34}

<table>
<thead>
<tr>
<th>Processing Technique</th>
<th>Fish type</th>
<th>Water usage</th>
<th>Wastewater</th>
<th>Solid waste</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>BOD 35kg, COD 50kg</td>
<td>490-640kg (including heads)</td>
</tr>
<tr>
<td>Average technologies</td>
<td>White fish</td>
<td>5-11m³</td>
<td>BOD 50kg, COD 85kg</td>
<td>400-450kg</td>
</tr>
<tr>
<td></td>
<td>Pelagic (herring)</td>
<td>5-8m³</td>
<td>BOD 12kg, COD 17kg</td>
<td>490-640kg (including heads)</td>
</tr>
<tr>
<td>Adopting BAT</td>
<td>White fish</td>
<td>1.2-4.4m³</td>
<td>BOD 12-15kg, COD 20-21kg</td>
<td>400-450kg</td>
</tr>
<tr>
<td></td>
<td>Pelagic (herring)</td>
<td>2.5-3.0m³</td>
<td>BOD 12-15kg, COD 20-21kg</td>
<td>400-450kg</td>
</tr>
</tbody>
</table>

### Table 31: Wastewater characteristics for various seafood species (UNEP figures)^{34}

<table>
<thead>
<tr>
<th>Species</th>
<th>Water usage (m³/tonne)</th>
<th>BOD (kg/tonne)</th>
<th>Suspended solids (SS) (kg/tonne)</th>
<th>Oil &amp; grease (kg/tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine finfish</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional plant</td>
<td>5</td>
<td>3</td>
<td>1-2</td>
<td>0.4</td>
</tr>
<tr>
<td>Mechanised plant</td>
<td>14</td>
<td>12</td>
<td>9</td>
<td>2.5</td>
</tr>
<tr>
<td>Shrimp</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frozen product</td>
<td>73</td>
<td>130</td>
<td>210</td>
<td>17</td>
</tr>
<tr>
<td>Breaded product</td>
<td>116</td>
<td>84</td>
<td>93</td>
<td>N/A</td>
</tr>
<tr>
<td>Salmon plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional plant</td>
<td>4-5</td>
<td>2-3</td>
<td>1-2</td>
<td>0.2-8</td>
</tr>
<tr>
<td>Mechanised plant</td>
<td>19-20</td>
<td>45-51</td>
<td>20-25</td>
<td>5-7</td>
</tr>
<tr>
<td>Mussel</td>
<td>20-120</td>
<td>60</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### 6.3 Data collection within current project

In both the telephone survey and the detailed data collection work, companies were asked to provide the following information:

- quantity of water used by site annually (m³);
- annual bill for water usage;
- strength of effluent generated;
- method of disposal of effluent;
- annual bill for effluent treatment; and
- measures taken to minimise water usage.

The majority of these questions were poorly answered, as many respondents could not readily access information on company water usage. Of 190 processors interviewed in the telephone survey, only 49 (26%) provided any data on water usage. The question relating to effluent strength received an even lower response rate of 6% (11 respondents).

Additional data was obtained from seven of the companies who participated in the detailed data collection, and three companies who carried out Envirowise Waste Prevention Reviews (WPR) with a focus on water usage. These additional sources of information are included in our analysis.

#### 6.3.1 Data limitations

The issue of data availability is highlighted above. Any conclusions or trends surmised about water usage in this project are therefore derived from a small sub-set of respondents. Of the companies who did provide data to the telephone survey, it is apparent that many of these figures are purely estimates rather than accurate figures on
water usage. Even data provided from the WPRs is, in some instances, based on estimates as companies could not provide accurate usage figures and had limited metering.

Figures for water usage per tonne of material were based on a company’s overall operations, and therefore should not be considered to be representative of a specific process. For example a company may carry out filleting of some, but not all, of their raw material. The figure quoted for a company carrying out filleting (for example in Table 32) may, therefore, not be an accurate reflection of the water usage to fillet a tonne of fish.

Figures on effluent strength provided were sometimes the maximum limit for effluent strength that had been agreed with the water provider. Actual figures may, therefore, be significantly lower in some instances.

6.3.2 White fish

Of the companies who provided data to the current study, 11 companies were solely processors of white fish. The majority of these, nine of 11, carried out filleting and six of 11 carried out thawing.

Of the 11 companies who provided data, in some instances data appeared inconsistent with expectations. For example, this included two companies who reported a water usage of <1m$^3$ per tonne of material while carrying out both thawing and filleting. This is below the levels of water usage which should be achievable using BAT. An assessment of the data provided by these companies indicated that figures provided were estimates only rather than accurate data, and these companies were therefore excluded from any further analysis. An additional processor was unable to provide an estimate for tonnes of fish processed, making it impossible to calculate water use per tonne of material.

Data provided by the remaining six white fish processors on water usage and effluent strength is shown in Table 32. It is noteworthy that only four of these companies provided figures for effluent strength.

<table>
<thead>
<tr>
<th>Filleting</th>
<th>Thawing</th>
<th>Secondary processing</th>
<th>Number of companies</th>
<th>Water usage (m$^3$/tonne)</th>
<th>COD (mg/L)</th>
<th>SS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>5-8.89</td>
<td>75$^{a)}$</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>1</td>
<td>5.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>1</td>
<td>2.50</td>
<td>5500</td>
<td>1000</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>1</td>
<td>1.0</td>
<td>223</td>
<td>339</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
<td>9.16</td>
<td>392</td>
<td>858</td>
</tr>
</tbody>
</table>

$a)$ 1 respondent only

The results shown in Table 32 indicate that the water usage reported in the current project is generally lower than that obtained in Seafish’s previous work. However, these results should be treated with caution due to the prevalence of estimation in the current work, making figures quoted less reliable than those obtained by the detailed audits of the previous study.

6.3.3 Shellfish

Eleven shellfish only processors are included in the set of 49 companies who provided data on water usage. Of these, data for six companies is included in Table 33.

<table>
<thead>
<tr>
<th>Main species processed</th>
<th>No of companies</th>
<th>Water usage (m$^3$/tonne)</th>
<th>COD (mg/L)</th>
<th>SS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scallop</td>
<td>2</td>
<td>2.1-2.8</td>
<td>450-1340</td>
<td>100-1014</td>
</tr>
<tr>
<td>Crab</td>
<td>3</td>
<td>17-20</td>
<td>74$^{a)}$</td>
<td>489$^{a)}$</td>
</tr>
<tr>
<td>Scallop &amp; nephrops</td>
<td>1</td>
<td>≈8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Secondary processor; many species</td>
<td>1</td>
<td>0.7</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

$a)$ 1 respondent only

The data shown in Table 33 provides a useful indication of levels of water usage for scallop and crab processors.
Scallop: The two scallop processors whose data is included in Table 33 were both participants in the detailed data collection work, and data provided is known to be based on actual bills. These companies are operationally similar businesses both sourcing predominantly whole live scallop and carry out washing, shucking and freezing operations. Similar water consumptions per tonne are seen for these two operations, although there is considerable variation in effluent strength. The scallop and nephrops processor had a significantly higher waste usage per tonne, and this is believed to be due to high water usage from defrosting of nephrops and washing of scallops.

Crab: The three crab processors who provided data also represent similar operations, with all sourcing whole live crab, which is then picked, cooked and vacuum packed by the processor. Data provided in Table 33 was sourced through the telephone survey. Although a good level of consistency is seen between the levels of water usage reported by these three companies, it must be noted that this data may be based on estimated usage only in some instances. Only one company was able to provide figures on effluent strength.

Additional information on crab processing water usage was acquired through interviews with two crab processors in the detailed data collection work. These respondents highlighted the high water usage required by crab processing operations. Crab is cooked by boiling in water and the subsequent cooling may also be water dependent. Considerable cleaning and rinsing is also required throughout the process. These two companies were undertaking a variety of measures to reduce water usage. Measures included the use of smaller crab cookers to reduce the volume of residual water, use of air cooling and recycling of water where possible.

6.3.4 All finfish

No pelagic only or salmon/trout-only processors provided data on water, so it is not possible to produce any figures for average water usage by these type of operation.

If all finfish are considered together, a set of 23 processors (both primary and secondary) who only handle finfish were obtained. Of these companies:

- eight carried out both filleting and thawing;
- ten carried out filleting but no thawing;
- two carried out thawing but no filleting; and
- four carried out neither thawing or filleting.

As in previous datasets, results that were believed to be inconsistent with expected values were removed from the dataset.

<table>
<thead>
<tr>
<th>Types of operation</th>
<th>Number of companies</th>
<th>Water usage (m³/tonne)</th>
<th>COD (mg/L)</th>
<th>SS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filleting &amp; thawing</td>
<td>5</td>
<td>1.8-28</td>
<td>-</td>
<td>75(a)</td>
</tr>
<tr>
<td>Filleting</td>
<td>7</td>
<td>0.75-16.9</td>
<td>392-5500(b)</td>
<td>858-1000(b)</td>
</tr>
<tr>
<td>Thawing</td>
<td>2</td>
<td>0.3-1.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neither</td>
<td>3</td>
<td>1-5.3</td>
<td>223(b)</td>
<td>339(b)</td>
</tr>
</tbody>
</table>

(a) 1 respondent only

(b) 2 respondents only

For this data set the variation in water use seen is too large to enable any meaningful conclusions to be reached. The large range in values seen will be strongly driven by the high level of variation which will exist within what is a very operationally diverse set of companies.

6.4 Water minimisation within seafood processing

All processors were asked about measures they had taken to minimise water usage within their operations, and the level of responses to these questions was far higher than those for water usage.

Of the 190 processors questioned in the telephone survey, 138 (73%) said they had undertaken measures to minimise water usage, including:

- 116 (61%) had carried out staff training;
- 46 (24%) used flow restrictors;
33 (17%) used spraying instead of soaking for filleting or washing operations; 34 (18%) had new equipment which minimised water usage; and 29 (15%) had installed metering of individual processes.

For all of the above measures, the uptake of approaches was generally higher for larger companies. Table 35 shows the percentage of companies of different sizes who had adopted measures to minimise water usage. Although the data set for very large companies from the telephone survey is very small, an additional two companies in the >500 employees band participated in the detailed data collection work, and confirmed that they were also actively pursuing a range of measures to minimise water usage.

Table 35: Percentage of companies who have taken measures to minimise water usage

<table>
<thead>
<tr>
<th>Company size (number of employees)</th>
<th>&lt;10</th>
<th>10-49</th>
<th>50-99</th>
<th>100-499</th>
<th>&gt;500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of companies</td>
<td>71</td>
<td>82</td>
<td>22</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Percentage adopting water</td>
<td>73%</td>
<td>63%</td>
<td>95%</td>
<td>85%</td>
<td>100%</td>
</tr>
<tr>
<td>minimisation measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Companies were also asked about measures that they had taken to reduce the effluent strength of their waste water, with the following responses being obtained from the 190 processors questioned in the survey:

- 149 (78%) used catch baskets or interceptors to prevent solids going to drain;
- 56 (29%) carried out settlement or filtration to remove solids before disposal;
- 68 (36%) used wire screens to separate out solids; and
- 20 (11%) had adopted no measures.

As with water minimisation measures, there was a noticeable trend for higher levels of measures to minimise effluent strength among larger companies.

The high proportion of companies taking measures to reduce water use indicates that this is an area of concern to the industry. Discussion with companies participating in the detailed data collection also confirmed that many are concerned about the increasing costs which their water usage incurs. Many are looking at how they can move away from traditional methods used for fish processes to methods that use less water. As a result of these discussions, three companies undertook Envirowise Waste Prevention Reviews (WPRs) which focused on minimising water usage.

Common themes which arose from our discussions included the following:

- **Defrosting and thawing operations**: Traditionally these have involved either immersion of fish or use of continually running water. Participant companies reported using heated rooms to defrost and recycling of water. Several had invested or were planning to invest in new equipment to minimise water usage of these operations.
- **Cooling**: Participants report use of air cooling or recycling of water used for cooling.
- **Machinery water usage**: Some participants highlighted that mechanical processes were often responsible for higher water usage than manual operations. One company commented that replacement of a wash-through separation process with a size-based separation process had led to considerable savings in water usage.
- **Cleaning**: Some participating companies also highlighted the fact that cleaning and hygiene requirements make a high contribution to water usage. Several companies stated that they have taken measures to reduce the impact of cleaning with the most common approach being to sweep up solid wastes rather than wash to drain. However, observations from WPRs showed that some companies are still using water to ‘chase waste’ to drains.

### 6.5 Water usage case studies

The three Envirowise waste prevention reviews (WPR) carried out for processors in this project all focused on reviewing companies’ water usage and identifying areas where efficiency savings could be made. The key findings of these reviews are summarised in the following brief case studies.
6.6 Conclusions: processors’ water usage

6.6.1 Water usage trends

The data collected (Tables 32-34) shows the high level of variability that exists in water usage in the seafood processing sector. Processes such as filleting, thawing and washing intrinsically use high volumes of water, and the water usage of a company will therefore be extremely dependent on the type of raw material sourced and operations carried out. Based on the results obtained in this study, it is generally not possible to ascertain how much of the variation was due to differences in companies' operations, and how much may be due to differing efficiencies of water use.

A simple comparison of the data for white fish processors (Table 32) with Seafish’s previous data (Table 29) indicates that participants in the current study have a lower level of water usage. However, the very small data sets and high levels of variability from both studies make it impossible to determine whether this represents a genuine trend towards reduced water usage by this sector of the industry.

Data from scallop and crab processors provided an indication of the level of water usage that may be expected for these two specific sub-sections of the shellfish processing sector. These results show far higher water usage for crab than scallop, which may be mainly driven by the high water requirement of the crab cooking process, compared to largely dry scallop preparation process. There are, however, no existing figures on expected or BAT water use for these types of operation that can be used for comparison.
For all other areas of the seafood industry it was not possible to draw any conclusions on the range of expected water usage. This was predominantly due to both the low response rate to questions on water usage, and the fact that many respondents undertake a wide range of operations across a wide range of species. Requesting information on individual process water use was beyond the scope of this study, and it is therefore generally not possible to attribute water usage by species or operation. Furthermore, as survey responses showed that only a minority (15%) of companies have introduced metering of individual processes, it is extremely unlikely that this information would be available.

Some very useful information was gathered from the Envirowise WPRs, which showed that for all three companies there are very simple measures which could be adopted (for example, turning off water flows when not in use, and improving efficiencies of cleaning processes). These are measures suggested in Seafish’s earlier water efficiency work, and this highlights the need for further assistance to the industry to ensure that these ‘quick wins’ are implemented.

6.6.2 Conclusions & Recommendations

The study shows that a high proportion of companies are taking measures to minimise water, and the emphasis placed on this by many participants indicates that it is an area of concern to the industry. Of the methods suggested by Seafish’s previous work, it appears that the simplest measures such as staff training (for example to turn off taps), have been widely utilised. Additional measures, such as the use of flow restrictors and spraying rather than soaking, would also appear to have to have been adopted to some extent by the industry. It is, however, impossible to say how effectively and comprehensively such measures may have been implemented. For example, previous work by Seafish has shown that catch baskets may be present in companies but not be used effectively. Likewise, information from the WPRs also shows that, at least for these participating companies, there is further scope to make considerable efficiency savings.

Detailed water audits would be required to confirm the real effect that water minimisation measures are having on industry water usage, and also the extent to which these measures are being effectively implemented by companies.

There is a general trend for big companies to implement more measures, and it would be envisaged that these larger companies may have a lower water usage per tonne of fish processed. However, not enough data was available from the current study to evaluate water use per tonne by company size.

The lack of detailed information on process water usage makes it difficult to assess the extent to which water usage could be improved. It is therefore recommended that a series of detailed water audits could be carried out to benchmark water usage and effluent generation for a range of operations; for example finfish filleting or cooking of crab.
7.0 Estimations of CO\textsubscript{2}e and economic impacts

This section includes estimates of the greenhouse gas (GHG) emissions and costs associated with the production of a number of seafood products, the utilisation of co-products and by-products, and the disposal of waste.

The production and reduction of GHG emissions have become increasingly important issues in recent years, as businesses strive to reduce their environmental impact. Typically, GHG emissions are measured to take into account all the different stages of production, and estimate the impacts of each stage to generate a total figure for the GHG emissions associated with a product. It is measured as carbon dioxide equivalent (CO\textsubscript{2}e), and enables comparison of options for different stages of the supply chain, including by-product utilisation or waste disposal. This enables a business to make informed changes if they want to reduce their environmental impact, i.e. changing a high impact process to one with less impact. In the context of this study, this is useful to identify whether there are opportunities to reduce the environmental impact of seafood production by addressing the options for co-product utilisation or waste management.

Data on GHG emissions related to seafood production is currently limited, and further information was gathered to provide estimates.

Within their respective supply chains, seafood species are sourced from numerous locations, both domestic and from imports, often in a range of different formats, processed to different extents and sold as numerous different product types. Due to the complexities of the seafood supply chains and the number of variables within each, it is impossible to generate data for each species on an industry-wide basis. Equally it is impossible to use the data gathered to generate an overall, industry-wide estimate for all seafood species. Instead, the use of detailed case studies provides an overview of the costs and relative impacts of different parts of specific supply chains for a number of different species.

The shortlist of species selected to review in detail were:

1. **Haddock** – Trawl caught Icelandic haddock (*Melanogrammus aeglefinus*) sold to UK restaurant;
2. **Mackerel** – Trawl caught smoked mackerel (*Scomber scombrus*) sold to UK multiple retailers;
3. **Salmon** – Farmed Atlantic salmon (*Salmo salar*) sold as fresh fillets to UK multiple retailers;
4. **Crab** – Pot/creel caught Brown crabs (*Cancerus pagurus*) sold to UK outlets;
5. **Scallop** – Dredged King scallop (*Pecten maximus*) sold to UK outlets;
6. **Whelk** – Pot/creel caught whelks (*Buccinum undatum*) sold to UK outlets; and
7. **Nephrops** – Trawl caught Nephrops (*Nephrops norvegicus*) sold to EU outlets as frozen, whole animals

The scope of this work covered 'cradle to gate' which includes capture, through to supply to sales outlet, including retail or foodservice. The retail part of the supply chain was not included, although generic figures from other studies are provided.

**Figure 39:** Scope of analysis

```
Primary production (fishing, capture, aquaculture) → Primary and secondary processing → Supply (including transport) to retailer or food service outlet
```

7.1 Method of analysis / data generation

For each species, a seafood company was selected to gather specific data on the supply chain. This included data on costs, transport methods, product formats and yields, use of refrigeration and freezing, temperature controlled storage, waste production, packaging, water use and effluent production. The detailed information provided by the companies is confidential, so for each case study only a summary of the product supply chain is provided.

The results of the data collection were analysed using a methodology developed for Seafish for estimating greenhouse gas (GHG) impacts in the seafood supply chain. Further information on this approach and the model is included in Appendix B.

The methodology developed for Seafish uses a mass based approach, whereas PAS2050 (the standard for generating estimates of GHG emissions) advocates allocation by economic value. For seafood, data is more
readily available on volume rather than economic value. Economic values also vary significantly over time, for example fuel and energy costs, seafood raw material and sales costs. Therefore introducing economic allocation would undermine meaningful comparison across case studies.

The economic analysis was restricted to the relative share of total revenues generated by main product, co-product and waste product throughout the supply chain, based on the data provided by the companies.

Although most of the companies were able to provide data relating to throughput, sourcing, sales/outlets, processing methods and yields, accurate information on fishing methods, fuel usage at sea and energy consumption during processing was unavailable. It was outside the scope of this study to generate this information separately. Instead, published information or assumptions have been made regarding refrigeration plant, fuel consumption of fishing vessels and energy requirements of shellfish cooking lines. As such, the figures provided can only be considered as indicative of the selected product supply chains.

Each case study refers to a single ‘notional’ product supply chain. As such, the cases do not take into account variation in practice across the seafood industry and can only be considered as indicative.

### 7.1.1 Contributory factors to GHG impacts of seafood products

Specific stages and practices in the supply chain provide different contributions to the GHG impacts. The extent of these impacts depend on a number of factors, including the method of capture / fishing, transportation used (air, sea or road transport), the use of refrigeration for temperature control, i.e. chilled or frozen, and also the extent and nature of processing. Table 36 summarises the main stages in each supply chain and contributory factors in terms of GHG impacts.

**Table 36:** Stages involved in seafood supply chains and factors contributing to GHG impacts.

<table>
<thead>
<tr>
<th>Stage in chain</th>
<th>Explanation of stage</th>
<th>GHG contributory factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary production</td>
<td>Capture / fishing</td>
<td>Use of fuel on vessels</td>
</tr>
<tr>
<td></td>
<td>Aquaculture / rearing seafood</td>
<td>Provision of feed to farmed species</td>
</tr>
<tr>
<td>Transport</td>
<td>Movement and deliveries of products</td>
<td>Use of energy to power transport vehicles (air, sea or road)</td>
</tr>
<tr>
<td>Refrigeration related</td>
<td>Temperature control (chilled and frozen)</td>
<td>Use of energy to power refrigeration plant (includes refrigeration leakage)</td>
</tr>
<tr>
<td>Non-refrigeration related</td>
<td>Processing seafood into products destined for sale</td>
<td>Use of energy &amp; resources to produce seafood products e.g. energy for cooking, smoking, mechanised processing</td>
</tr>
</tbody>
</table>

Each product supply chain is broken down into these four main stages, with estimates of GHG emissions provided for each stage.

### 7.2 Results

A comparison of results for each product supply chain is provided in Table 37 and Figure 39. Table 37 provides a summary of all the results for the different supply chains, including revenues, costs and greenhouse gas (GHG) emissions. These figures are based on the production of one tonne of finished product.

The detailed results of the seven case studies are included in Appendix C.

**Table 37:** Summary of results for different supply chains, based on production of one tonne of finished product

<table>
<thead>
<tr>
<th>Case study</th>
<th>Product</th>
<th>Quantity caught (kg)</th>
<th>Total Co-product quantity (kg)</th>
<th>Total Co-product sales (£)</th>
<th>Total waste quantity (kg)</th>
<th>Total waste costs (£)</th>
<th>Total Revenue – sales (£)</th>
<th>Total GHG emissions (kg CO2e/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Haddock fillets (chilled)</td>
<td>2,834</td>
<td>1,381</td>
<td>£43</td>
<td>454</td>
<td>£0</td>
<td>£38,088</td>
<td>1,832</td>
</tr>
<tr>
<td>2</td>
<td>Smoked mackerel fillets (chilled)</td>
<td>3,055</td>
<td>1,711</td>
<td>£67</td>
<td>344</td>
<td>£0</td>
<td>£15,599</td>
<td>960</td>
</tr>
<tr>
<td>3</td>
<td>Salmon fillets (chilled)</td>
<td>1,764</td>
<td>238</td>
<td>£7</td>
<td>525</td>
<td>£0</td>
<td>£27,260</td>
<td>3,668</td>
</tr>
<tr>
<td>4</td>
<td>White crab meat (chilled)</td>
<td>13,333</td>
<td>3,667</td>
<td>£98,528£</td>
<td>8,667</td>
<td>£780</td>
<td>£70,913</td>
<td>11,159</td>
</tr>
<tr>
<td>5</td>
<td>Shucked scallops</td>
<td>5,000</td>
<td>3,000</td>
<td>£120</td>
<td>1,000</td>
<td>£80</td>
<td>£33,270</td>
<td>3,876</td>
</tr>
</tbody>
</table>
### Table

<table>
<thead>
<tr>
<th>Product</th>
<th>Volume</th>
<th>Weight</th>
<th>Value</th>
<th>Cost</th>
<th>Total Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooked whelk (chilled)</td>
<td>5,000</td>
<td>0</td>
<td>£0</td>
<td>-£180</td>
<td>£21,250</td>
</tr>
<tr>
<td>Whole Nephrops (frozen)</td>
<td>1,053</td>
<td>53</td>
<td>£316</td>
<td>0</td>
<td>£12,947</td>
</tr>
</tbody>
</table>

i- Includes waste from processing at sea  
ii- Includes sales of all product i.e. dressed crab, frozen white meat  
iii- Excludes revenue from final sale due to lack of data

---

**Figure 40:** GHG Emissions profiles of selected product chains

Comparison of these estimates with other protein-based food estimates is weakened by the fact that different methodologies are employed in studies undertaken. The results, although indicative, compare favourably to emissions estimates for seafood products shown in other studies. SINTEF studied a range of seafood products including herring, mackerel, cod, saithe (coley) and haddock from capture fisheries, and from aquaculture, blue mussels and salmon. This study found a range of carbon footprint of 1,000 to 14,000 kg CO₂e/t of edible product delivered to wholesaler, compared to 960 to 13,410 kg CO₂e/t in the detailed case studies. The results contrast with emissions estimates for other protein products. A study on the life cycle assessment for pork production shows a range of 8,600 to 9,800 kg CO₂e/t of product consumed. Pig production, (comprising feed growing and production, pig rearing and slurry) accounts for nearly three quarters of the pork products’ carbon footprint. The results show that for both farming and fishing, primary production is by far the most GHG intensive part of the supply chain.

#### 7.2.1 Food retailing

The majority of seafood sold to consumers is through multiple retailers (>80%). The specific GHG impacts associated with retail was outside the scope of the case studies. Previous work, funded by Defra, provides estimates of the GHG impacts of food retailing, the key findings from which are described below.

The scope of this Defra-funded study focussed on multiple retailers and included delivery from a regional distribution centre (RDC) through to handling and storage at retail, including associated transport. It also included disposal of food waste (but limited to landfill without recovery). The study included a range of chilled and frozen foods; however, it did not include any seafood products.

The results of the Defra funded study show the impact of retailing frozen and chilled foods varies from 477 to 1,124 kg CO₂e/t. The overall figures per food group (chilled or frozen only) are listed in Appendix C, as these are the same product groups as the majority of seafood supplies. However, it is impossible to use this data to provide an accurate estimate of the GHG emissions for retail of seafood products, due to variations in distribution and transport.
storage between the chilled and frozen products in the Defra study compared to the seafood products in the case studies.

The Defra study concluded that for most temperature-controlled products, energy consumption of refrigerated display cabinets and refrigerant leakage account for the vast majority, over 80%, of the emissions from the distribution and retail phase of the food product life cycle.

The average results show 677 and 789kg CO₂e/t for chilled and frozen foods, respectively, indicating that frozen foods have a slightly higher overall emissions burden than chilled foods. The impact of refrigerated display is typically higher for frozen foods compared to chilled foods, with the exception of chilled ready meals.

For all temperature controlled products, emissions from storage in Regional Distribution Centres, and to a lesser extent cold rooms in the supermarket, are quite small due to the short residence time and the large quantity of products stored per unit area or volume.

The impact of waste generation is a relatively small contribution to the overall impact of the retail of different foods. For each type of food, waste disposal has the same impact, i.e. 9.8 kgCO₂e/t, although this is only based on landfill without energy recovery.

Jackson et al.⁹ suggest 480kgCO₂e/t for landfill of food waste, which is a huge variation from the Defra study. Again, this is based on ‘food’ waste and not specific to seafood. Landfill is not used for the majority of seafood by-products or waste in the UK so is less relevant than, for example, fishmeal production. However, specific data on the emissions impact of other uses of seafood waste or disposal routes, including fishmeal, AD, composting and incineration, is less readily available and not discussed here.

7.2.2 Discussion of results

The results generated through these case studies reveal a wide range in GHG emissions, from 960kg CO₂ e/tonne to 13,410kg CO₂ e/tonne. Important factors here include the gear and fishing practices of the fleet segments concerned and the extent to which live-weight volumes produced are utilised to produce final product or co-product volumes. This, in turn, is influenced by the yield of the species in producing product and co-products. The most significant contrast is between the crab (in which 65% of the landed weight goes to landfill) and mackerel (in which all the processing trimmings are utilised). In summary the results suggest:

- Primary production, whether in fish capture of fish farming, is typically responsible for the largest share of GHG emissions. A notable contrast is the low emissions contribution made by the pelagic trawl (mackerel) compared to a shellfish dredge or trawl (scallops and nephrops). This is due to differences between the weight and drag of different types of fishing gear, which affect fuel usage and thus GHG emissions. Heavier fishing gear which is towed along the sea bed is typically more energy intensive than lighter gear which is towed through the water column. Feed provision dominates emissions for farmed salmon.
- Processing (i.e. the non-refrigeration element) generally makes small contributions to overall emissions, with the exception of those products processed to a high level, e.g. smoked mackerel or cooked crab. In these cases, the contribution of processing is influenced by the timescale and fuel intensity of the process. However, this is less apparent for cooked whelk, which is processed to a high temperature for only a short period of time.
- Transport related emissions are typically higher for imported and exported products and those from remote rural areas (as in the case of farmed salmon).
- Refrigeration makes a very small contribution to overall emissions.
- Retailing makes an additional contribution to overall emissions (based on the data from the Defra study). The emissions burden is slightly higher for frozen foods compared to chilled foods, but this largely depends on the food itself and the extent of processing. For the seafood products studied in detail, and using averages for frozen and chilled foods from the Defra study, food retail is typically less than 20% of the overall burden of each product, with the exception of smoked mackerel (41%) and haddock fillets (27%). Of all the case studies, these two products have the lowest overall emissions burden, hence retail makes a more significant contribution. However, these trends should be treated with caution as it is not possible to estimate the true impact of retailing, due to the lack of specific data for seafood.
- The ratios of waste and co-products vary significantly with each species. Finfish species typically generate income from both product and co-product sales, with the use of material for co-products an important part of the overall supply chain. Although shellfish may generate sales from co-products, a proportion of the shellfish is disposed of as waste at cost to the processor.
- There is a close relationship between the utilisation of co-product, the quantity of waste generated, and the emissions burden. High co-product usage and low waste generation provides a lower emissions burden, compared to a low co-product usage and high waste generation which has a higher emissions burden. However, a number of other factors contribute to the overall emissions burden, notably primary production.
Production of waste and use of co-products is not the primary contribution to overall GHG emissions of seafood products.

These findings are supported by research conducted previously by Seafish and others, as follows:

- Notably the dominance of the primary production stage, i.e. fishing or farming. Previous research has highlighted the role of fuel, and, in particular the degree to which fuel intensity is influenced by the abundance of the targeted stocks, the fishing technology employed and the distance to fishing grounds.
- Processing and packaging generally make very small contributions to overall emissions (often under 10% of total), except in instances in which emission-intensive materials are used (e.g. metals) or when cooking is involved.
- For intensively cultured products (e.g. salmon), emissions associated with feed provision, and consequently with primary resource production generally, often dominate full supply chain GHG emissions.
- GHG impacts associated with transport are typically higher for imported products compared to UK-sourced products. This is particularly noticeable for air freighted products compared to those that travel by sea and road.
- The contribution from refrigeration, even for frozen products, is a relatively small part of the overall emissions.
8.0 Conclusions and recommendations

8.1 Conclusions

The work carried out in this project has provided estimates of waste and co-product generation in both seafood processing and retail. Table 38 summarises these figures on a species-specific basis, and references these against quantities expected based on non-edible inputs. For pelagic and white fish processing, an estimate of the quantity of co-products which are sold to fishmeal plants has been incorporated to provide an estimate of the residual quantities which are designated as wastes. Although not quantifiable from our results, it is reasonable to assume that for salmon and trout a large volume of material is also utilised as co-products. However, for key species of shellfish, it is not possible to break down the combined figure into material which is utilised as a co-product or disposed of as a waste. We define co-products as material which achieves a value for the producer; consequently the majority of shellfish by-products are considered as wastes, as processors pay for their removal. This material may, however, be utilised in applications such as aggregate.

It is revealing to compare the estimates of 133,100 tpa total waste and co-products from processing, and 6,800 tpa from retail, with the previously derived estimate of 43,000 tpa of household fish waste. Simplistically this shows that processing is by far the biggest cause of seafood waste and co-products in UK supply chains. It must, however, be stressed that whereas the majority of consumer waste (32,000 tpa) is avoidable, material obtained from processing is predominantly unavoidable. Furthermore, a large proportion of this material, estimated at 77% for white fish and 95% for pelagics, is utilised as valuable co-products. It must, however, be stressed that whereas the majority of consumer waste (32,000 tpa) is avoidable, material obtained from processing is predominantly unavoidable. Furthermore, a large proportion of this material, estimated at 77% for white fish and 95% for pelagics, is utilised as valuable co-products. As noted above, it is not possible to distinguish between volumes of co-products and waste for all species, and therefore a total figure for processing waste cannot be derived. However, it can be assumed that a significant majority of the 105,200 tpa attributed to finfish processing is co-products utilised in fishmeal.

The complexities of seafood processing operations also make it impossible to produce an industry-wide estimate of avoidable waste, although our analysis strongly indicates that this is considerably lower than avoidable waste from households.

Table 38: Comparison of input volumes with waste & co-product generation

<table>
<thead>
<tr>
<th>Species</th>
<th>Total inputs (tpa)</th>
<th>Non-edible input (tpa)</th>
<th>Combined processing wastes and co-products (tpa)</th>
<th>Estimated processing wastes (tpa) b)</th>
<th>Retail waste (tpa)</th>
<th>Total UK waste and co-products a) (tpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cod</td>
<td>121,200</td>
<td>16,400</td>
<td>4,400±900</td>
<td>1,000</td>
<td>700</td>
<td>5,100</td>
</tr>
<tr>
<td>Haddock</td>
<td>103,600</td>
<td>37,300</td>
<td>23,900±2,000</td>
<td>5,500</td>
<td>600</td>
<td>24,500</td>
</tr>
<tr>
<td>Monkfish</td>
<td>18,000</td>
<td>11,100</td>
<td>4,900±400</td>
<td>1,100</td>
<td>&lt;100</td>
<td>4,900</td>
</tr>
<tr>
<td>Pollock</td>
<td>44,000</td>
<td>13,200</td>
<td>7,500±700</td>
<td>1,700</td>
<td>200</td>
<td>7,700</td>
</tr>
<tr>
<td>Plaice</td>
<td>27,700</td>
<td>9,400</td>
<td>5,700±500</td>
<td>1,300</td>
<td>100</td>
<td>5,800</td>
</tr>
<tr>
<td>Whiting</td>
<td>11,800</td>
<td>7,000</td>
<td>4,000±300</td>
<td>900</td>
<td>&lt;100</td>
<td>4,000</td>
</tr>
<tr>
<td>Herring</td>
<td>50,400</td>
<td>22,300</td>
<td>4,900±1600</td>
<td>200</td>
<td>&lt;100</td>
<td>4,900</td>
</tr>
<tr>
<td>Mackerel</td>
<td>154,100</td>
<td>70,300</td>
<td>11,800±3,800</td>
<td>600</td>
<td>600</td>
<td>12,400</td>
</tr>
<tr>
<td>Tuna</td>
<td>124,000</td>
<td>300</td>
<td>≈200</td>
<td>-</td>
<td>800</td>
<td>1,000</td>
</tr>
<tr>
<td>Salmon</td>
<td>192,300</td>
<td>57,800</td>
<td>33,200±8,400</td>
<td>-</td>
<td>1,800</td>
<td>35,000</td>
</tr>
<tr>
<td>Trout</td>
<td>14,400</td>
<td>5,300</td>
<td>4,700±1,200</td>
<td>-</td>
<td>200</td>
<td>4,900</td>
</tr>
<tr>
<td>Crab</td>
<td>28,400</td>
<td>17,700</td>
<td>6,800±1,300</td>
<td>-</td>
<td>&lt;100</td>
<td>6,800</td>
</tr>
<tr>
<td>Scallop</td>
<td>32,200</td>
<td>26,000</td>
<td>14,400±6,900</td>
<td>-</td>
<td>&lt;100</td>
<td>14,400</td>
</tr>
<tr>
<td>Nephrops</td>
<td>45,500</td>
<td>30,800</td>
<td>6,700±4,900</td>
<td>6,700</td>
<td>&lt;100</td>
<td>6,700</td>
</tr>
<tr>
<td>CWP</td>
<td>29,000-45,000</td>
<td>Minimal</td>
<td>Minimal</td>
<td>Minimal</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>WWP</td>
<td>48,000</td>
<td>Minimal</td>
<td>Minimal</td>
<td>Minimal</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Mussels</td>
<td>28,800</td>
<td>24,800</td>
<td>Minimal</td>
<td>Minimal</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>104,400</strong></td>
<td><strong>349,700</strong></td>
<td><strong>133,100</strong></td>
<td><strong>6,800</strong></td>
<td><strong>139,900</strong></td>
<td></td>
</tr>
</tbody>
</table>

a) Figure includes waste and co-products from processing and retail.
b) These figures are derived from estimates of combined processing waste and co-products. Estimates of the proportion of this material which is utilised as co-products allow an estimate of waste to be made. For example, approximately 77% of white fish and 95% of pelagic processing by-products are sent to fishmeal; in this analysis the remaining 23% white fish and 5% pelagics (which may be disposed of or recovered by a range of mechanisms) is designated as waste.
Our analysis has produced an estimate of 5% retail waste from multiple retailers for fresh fish products. This compares reasonably well with the figure of 6% which can be extrapolated from a previous WRAP study on food and drink supply chains. These two figures represent two very different approaches to estimating waste arisings. Used in conjunction, however, they can be considered to provide an indicative view of the level of waste generated by the multiple retailers. This volume appears relatively insignificant when compared to the figures for both processing and household waste; it is noteworthy that the majority of this waste will be avoidable.

8.1.1 Waste and co-product generation
The following main conclusions can be drawn on the reasons for waste and co-product generation in seafood supply chains:

- The majority of waste and co-products created in processing is unavoidable, non-edible components.
- A processor’s waste and co-product outputs are highly dependent on the operations carried out. Those carrying out filleting of finfish or picking/shucking/peeling of shellfish will inevitably have higher arisings than other processors.
- Volumes of waste and co-products are highly species and input format dependent; two primary processors of haddock may have very different arisings depending on whether their primary raw material format is fillets or whole fish.
- An individual processor’s operations are often highly variable, and it is therefore difficult to identify their expected unavoidable waste (and by inference the avoidable waste) from overall figures on waste volumes.
- Quantities of avoidable waste cannot be estimated from the data collected in this study, as these relatively small volumes are ‘lost in the noise’ of the much higher non-avoidable waste arisings.
- A comparison of edible inputs and product volumes generally indicates that avoidable waste arisings within processing are low.
- Quantities of waste and co-products produced in retail are comparatively low, but will be predominantly avoidable.

To accurately quantify avoidable waste arisings within seafood processing it would be necessary to carry out a series of detailed audits at a range of processors, focusing on the waste generated by a specific process. For example, comparison of filleting yields and monitoring of edible fish discarded for a range of companies may enable average and BAT figures for this operation to be derived.

8.1.2 Waste and co-product utilisation
The following trends can be observed for the major disposal and utilisation mechanisms for material obtained at different stages of the supply chain:

- **Finfish processing:** The majority of co-products from finfish processing are sent to fishmeal plants. This is estimated at 77% for whitefish and >95% for pelagics. This both generates valuable secondary products and represents a source of income to processors.
- **Shellfish processing:** Utilisation of shellfish by-products can be problematic to processors, as limited outlets currently exist for shell which is produced in large quantities by many operations. Shell has a range of possible markets as aggregate, filtration media or for decorative purposes, but exploitation of these markets is currently difficult due to the need to comply with ABPR and Environment Agency legislation. Disposal of flesh waste can also be very expensive and is dependent on the availability of local ABPR-compliant facilities.
- **Retail:** The requirement for ABPR compliance coupled with a focus on reducing waste to landfill means that most retail fish waste from multiples is either rendered or converted into pet-food.
- **Packaging wastes (processors):** The most common types of packaging wastes identified by processors were EPS boxes, cardboard and plastic tubs associated with transport of fish. The majority of this material is recycled or re-used.

A general theme from processors is that some are not clear exactly what mechanisms are acceptable for treatment and disposal of seafood by-products. The involvement of more than one regulatory body only serves to increase this confusion (the Environment Agency is responsible for waste disposal and approving utilisation of co-products, whereas Animal Health is responsible for compliance with ABPR).

The ease of disposal or utilisation is greatly influenced by a company’s geographical location and the accessibility of suitable outlets. For example, sale of co-products to fishmeal plants is only viable if a plant exists within a reasonable distance. However, the biggest problems are experienced by shellfish processors, many of whom are in remote areas and may be more than 50 miles away from an ABPR-compliant disposal site.
8.1.3 Waste minimisation: Fish

Within processing, initiatives to ensure maximum yields are relatively common and processors are generally adamant that avoidable waste is insignificant. Discussions during the survey indicated that a range of waste minimisation measures have been adopted by companies, generally driven by the need to maximise value from the fish and shellfish processed. The most common measures adopted include the following:

- staff training;
- process monitoring;
- use of target yields for filleting processes;
- use of catch trays to minimise fish dropped on floor;
- machinery to maximise meat recovery; and
- use of rejected (e.g. out-size) fish in secondary products.

Fish is a high value raw material and processors generally focus on waste minimisation for predominantly economic reasons. Maximising sales value is a strong driver and has resulted in generally low wastage throughout the industry.

Retailers also undertake a range of measures to minimise the waste derived within their operations. However, it is noteworthy that the multiple retailers could generally not provide information on the final quantities of waste produced within their operations. It is, therefore, difficult to monitor improvements which may be derived from the measure adopted. The most common approaches, which were used by most multiples, include the following:

- use of mark-downs to sell products close to sell by dates;
- shelf-stacking to maximise shelf-life;
- control of stock ordering/forecasting; and
- monitoring storage temperatures in refrigeration units.

8.1.4 Waste minimisation: Packaging

A high proportion of processors, 45% of primary and 63% of secondary, reported that they are taking measures to minimise packaging waste. Measures adopted include packaging light-weighting and moves to alternative materials. There is a notable trend that large companies are more likely to have undertaken such measures, but a significant number of smaller firms also appear active in this area.

All of the multiple retailer participants were actively pursuing a range of options, both to minimise the volume of packaging passed to consumers and to reduce waste arisings within their own operations. Measures adopted included:

- Light-weighting of packaging by use of novel packaging designs and alternative materials; and
- Replacement of EPS fish boxes with alternative reusable and recyclable transit packaging.

8.1.5 Water usage

A high proportion, 73%, of seafood processors report taking measures to minimise water usage, and many companies expressed concern about the impact of rising water and effluent costs on their operations. The most common measures adopted include staff training, flow restrictors and the use of catch baskets to prevent solid waste going to drain. Despite their concerns, few companies have installed water meters for individual processes, and are therefore unable to robustly record their waste usage. Only a minority of companies were able to provide data on their overall company water usage, and this lack of data availability makes it impossible to quantify the effectiveness of minimisation measures undertaken, or to robustly benchmark a company’s performance.

For the small set of companies who were able to provide water usage figures, the data shows a high level of variability exists in water usage in the seafood processing sector. Processes such as filleting, thawing, cooking and washing intrinsically use high volumes of water, and the water usage of a company will therefore be extremely dependent on the type of raw material sourced and operations carried out.

Indicative results for water usage were obtained for specific areas of seafood processing: notably white fish, crab and scallop processing. These results showed a high level of variability in the white fish sector, with filleting and thawing appearing to be major water using stages. A comparison of figures for crab and scallop indicates that crab processing, which includes cooking in water, is much more water intensive than the largely dry scallop preparation process. Further work would be required to establish whether the small data set obtained in this work is indicative of these sectors overall.
There is currently limited data available from other sources which can be used to benchmark water use of companies or processes. Based on the results obtained in the current study, it is not possible to ascertain how much of the variation seen is due to the diversity of companies operations, and how much may be due to differing efficiencies of water use.

8.1.6 Impacts of waste

The study carried out to evaluate carbon and economic impacts of waste was based on a set of seven diverse case studies showing where major impacts arise in specific supply chains. This work provides the following conclusions.

- Considerable variability exists between these different supply chains; a simple 'industry-wide' figure for impact of waste is therefore not achievable.
- Results generated through these case studies reveal a wide range in GHG emissions, from 960 kg CO₂ e / tonne to 13,410 kg CO₂ e / tonne of final product.
- Primary production, whether in fish capture or fish farming, is responsible for the largest share of GHG emissions.
- Variation in gear and practices used by the fleet have a very significant influence on the impact due to fishing practices; a notable contrast is the low emissions contribution made by the pelagic trawl (mackerel) compared to the shellfish trawl (scallops and Nephrops).
- GHG emissions from transport are generally higher for imported or exported products by comparison to fish which is sourced and used within the UK.
- Processing generally has a very small impact on overall emissions associated with a product.
- The impact of retailing of fish products cannot be quantified from existing data, but is expected to represent a noticeably additional impact.
- Utilisation of co-products can have a noticeable impact on the emissions burden of a product; for example, use for fishmeal or markets for shell provides a lesser impact compared to landfill.

8.2 Recommendations

8.2.1 Identification of avoidable waste streams in processing

A key finding of this work is that, based on the data obtained, it is not possible to quantify avoidable waste arisings within processing. This is driven by both the variability of operations and the high volumes of non-edible components, which mean avoidable wastes are ‘lost in the noise’ of the much higher figure of unavoidable materials. These avoidable wastes are generally assumed to be minimal; however, it would be beneficial to quantify this figure for specific operations and to understand the variability which exists between companies. The following recommendation is therefore made.

- Perform a series of detailed waste audits at companies to assess and benchmark the level of avoidable waste produced by key operations such as filleting, shucking or picking.

8.2.2 Improved mechanisms for disposal of shellfish co-products

A key area where implementation of new measures has potential to offer significant benefits is the use of shell by-products. From the data obtained in this project, it is not possible to identify the quantity of material which is currently utilised in alternative markets versus material which is disposed of. However, some of this material is currently disposed of to landfill due to a lack of other available options, as processors are unable to exploit the many markets which potentially exist for this material. The following recommendations are therefore made:

- To clarify the definition of ‘free-of-flesh’ shell: ABPR states that free-of-flesh shell can be used in other applications; however, within the UK it is currently not clear what material meets this classification. Seafish is currently defining a standard treatment methodology, which could be adopted to meet these requirements.
- Development of a Quality Protocol and PAS for shell: by applying a similar approach to that adopted for compost with PAS 100, clean shell, which is produced in accordance with the specification, could be classified as a product rather than as a waste.
- Development of markets for shell products. Potential applications include aggregates, filter media or for decorative purposes.
- The ABPR is currently under revision and EU member states can develop their own standards. It also allows for the development of guidance to clarify what the member states are proposing to implement. An assessment of the risk posed by utilisation of shell, in contrast to other types of ABP, should help with identification of a proportional approach. For example, this may provide scope to exclude free-of-flesh shell from the scope of the regulation.
Shellfish processing also produces waste flesh such as viscera, and disposal of this material can also be problematic for the industry. This material is not acceptable to fishmeal plants so other ABPR-compliant mechanisms must be used. Many shellfish processors are located in remote areas where access to suitable facilities is limited. This can result in companies transporting material a considerable distance for disposal; an approach which is neither economically or environmentally desirable. Alternatively material may be disposed of by non-compliant mechanisms including sending to landfill.

The following recommendations are therefore made:

- To review the geographical spread of ABPR-compliant facilities, such as in vessel composting (IVC) and AD, that provide compliant and sustainable options for disposal of shellfish flesh waste. Identify areas where significant volumes of suitable waste are available but current treatment infrastructure is limited.
- Development of mechanisms to encourage installation of suitable, cost effective disposal facilities in these areas.

The availability of a greater range of ABPR-compliant facilities could also be beneficial to some finfish processors in remote areas where access to fishmeal plants is limited. It should, however, be stressed that fishmeal remains the preferred method of disposal for finfish co-products.

8.2.3 Optimising water usage

Water usage is an area for concern for many seafood processors. Although the majority of companies are undertaking measures to reduce their water usage, responses to the survey indicate that many do not have a clear view of current consumption. A very low proportion indicated that they have metering facilities on individual processes. A key mechanism to promote efficient use of water within the industry would be the ability to robustly monitor water usage. The following recommendations are therefore made:

- Promote proactive monitoring of water usage. Encourage and incentivise companies to install individual process water meters.
- Promote awareness of cost savings which can be achieved by adopting simple, low cost water reduction measures.
- Benchmarking of process water usage. Carry out water audits at a range of companies to record process specific water usage and effluent generation for a range of operations (e.g. for filleting or cooking of crab), and to provide an up-to-date view of average and best practice water usage.
- Encourage companies to sign up to the FHC or Rippleffect to help to address water usage.

These measures should predominantly target small and medium-sized companies, as these organisations tend to not have the resources available to undertake such measures on their own. Companies of this size represent the majority of seafood processors in the UK, and are also the organisations where potentially the greatest scope for improvement exists.

8.2.4 Optimising packaging usage

Considerable efforts are being made by both retailers and processors to reduce the quantity and impact of the packaging used for their products. However, the requirement for fish to be transported and stored with effective temperature control necessitates the use of thermally insulating packaging.

Traditionally, EPS has been the material of choice, driven by its light weight and excellent insulation properties. However, the poor environmental image of EPS is leading to investigation of other approaches. EPS is readily recyclable or its considerable calorific value can be exploited via incineration with energy recovery. However, both options require compaction as a first step and this is only a viable option for companies with a significant quantity of waste. Consequently, landfill is still the only available option in some cases.

Replacing EPS with other materials is not a simple proposition as many possible alternatives have poorer insulation properties. Additionally, the whole life cycle impacts of a material must be considered. Heavier re-useable materials may result in lower waste to landfill but may also increase the energy requirement for transportation.

It is therefore recommended that:

- A study of the relative life cycle impacts of a range of fishbox options should be carried out to provide a clear view of the preferred packaging approach for transportation of fish.
Appendix A: Methodology for data extrapolation

For the purposes of quantitative estimation of wastes arising, and comparison of survey data with external data sources, the following procedure was adopted.

1 Data from the telephone survey was combined with compatible information derived from detailed interviews. Following an initial scan of the information provided, any obviously suspect data was verified with respondents wherever possible, and erroneous information (usually due to misunderstanding of the required units or time period for answers) was corrected. Where respondents confirmed unlikely looking values, these were taken forward for further analysis, where they were assessed for potential undue leverage (influence over the conclusions drawn). Remaining unexplained gross outliers were excluded.

2 Percentage waste was calculated for those providing quantified annual tonnage estimates of both raw materials and waste. Claimed waste levels of 0% or greater than 100% of raw materials were noted, but eliminated from further analysis.

3 Data was segmented by the four major categories:
   - White fish;
   - Pelagic;
   - Shellfish; and
   - Salmon and trout.

4 Within each segment, data was further divided into the four identified categories of business activity:
   - Primary processing (including those identified as both Primary and Secondary processors);
   - Secondary processing;
   - Wholesale; and
   - Retail.

5 For primary processing, data was further stratified into operational unit size bands, and the effect of size on Percentage Waste examined by Analysis of Variance (multiple comparison of means). No significant differences were detected at the 5% Significance Level.

6 Returns from all processors (Primary and/or Secondary) were subjected to further exploratory segmentation by class of unit operations anticipated to be associated with major quantities of unavoidable waste arising.

   The following segments ultimately proved to be useful:
   - For white fish, pelagic fish, and salmon and trout, gutting, filleting, or skinning were associated with high levels of waste. From a data analysis point of view, the terms were virtually synonymous; nearly all processors who gut, also fillet etc. These operations were collectively regarded as representing the processing of "Whole Fish", while other operations were collectively taken as the processing of "Fish Fillets". This approach allowed the comparison of reported waste levels with theoretical unavoidable wastes, and estimated inputs of "Whole Fish" and "Fillets" from external sources.
   - Similarly for shellfish, segmentation was applied to: shucking for scallops; peeling for prawns (Cold and Warm Water Prawns combined) and nephrops; and picking for crabs.

7 Confidence intervals for estimates of waste were expressed as Margins of Error at the 95% Confidence Level.

Extrapolation of estimate of processing wastes for resource mapping

8 The segmentation strategy applied to reported waste in the survey at Point 6 had a corollary in the incoming resource streams, identified for each of the four categories of seafood (and individual species). That is, Imports and Landings were as far as possible categorised by their proportions of "Whole Fish" or "Fish Fillets" (for white fish, pelagic fish and salmon and trout) or "Whole Shellfish" / "Deshelled" for shellfish species.
<table>
<thead>
<tr>
<th>State</th>
<th>&quot;Fillets&quot;</th>
<th>&quot;Fish&quot;</th>
<th>&quot;Fillets&quot;</th>
<th>&quot;Fish&quot;</th>
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<tr>
<td>Percentage of Total</td>
<td>85%</td>
<td>15%</td>
<td>0%</td>
<td>100%</td>
<td>74%</td>
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<tr>
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### Unavoidable Waste

<table>
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<th>58%</th>
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</thead>
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<tr>
<td>Whole</td>
<td>64%</td>
<td>&quot;Fillets&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated Unavoidable Waste</th>
<th>0%</th>
<th>51%</th>
<th>0%</th>
<th>60%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>8,131</td>
<td>0</td>
<td>9,758</td>
</tr>
</tbody>
</table>

#### From the total inputs (and expected wastes arising), the amount of seafood going directly to exports, without going through processing, was removed. In some cases, this is a large amount, while in others it is fairly negligible. For the example of cod:

\[
\text{Whole Fish Input to Processing} = \text{Whole Fish Landings} - \text{Fish to Direct Exports} \\
= 32,300 - 24,600 = 7,900 \text{ tpa}
\]

The theoretical unavoidable waste content of this is roughly 4,350 tpa.

#### Estimates for the average percentage waste for the two segments from the survey were applied to the tonnages of "Fillets" and "Fish", and ultimately combined into a single estimate of wastes arising, with a 95% margin of error based on the overall size of the dataset and a combined internal estimate of error.

<table>
<thead>
<tr>
<th>From Survey</th>
<th>&quot;Fillets&quot;</th>
<th>&quot;Fish&quot;</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Average %Waste</td>
<td>2.8%</td>
<td>34.6%</td>
<td></td>
</tr>
<tr>
<td>Margin of Error</td>
<td>3.4%</td>
<td>3.1%</td>
<td></td>
</tr>
<tr>
<td>Estimate of waste</td>
<td>2,529</td>
<td>2,731</td>
<td>5,260</td>
</tr>
<tr>
<td>SD</td>
<td>3,390</td>
<td>912</td>
<td>3,510</td>
</tr>
<tr>
<td>Margin of Error</td>
<td>899</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower limit</td>
<td>-606</td>
<td>2,482</td>
<td>4,361</td>
</tr>
<tr>
<td>Upper limit</td>
<td>5,664</td>
<td>2,980</td>
<td>6,160</td>
</tr>
</tbody>
</table>
Appendix B: Methodology for Estimation of GHG estimates in seafood chains

Adapted from CO₂ emissions, Case studies in selected seafood product chains, Version 1, Spring 2008 (Garrett, Tyedmers and Anton, 2008), based on earlier research conducted by Angus Garrett and Susan Anton of Seafish, UK, and Peter Tyedmers and Nathan Pelletier of Dalhousie University, Halifax, Nova Scotia, Canada. http://www.seafish.org/co2emissions/

Seafood processing companies were approached as the main industry contacts, because of their ability to leverage data along product supply chains. A simple flow chart was designed to assist processors in providing a broad overview of the product supply chains.

For most product chains of interest, companies were asked, either by telephone interview or email, to provide data regarding their product supply chains using simple flow charts as a starting point. These data were used to populate product chain-specific GHG emission calculators. Companies were then re-contacted for additional information or clarification where gaps or contradictions were identified. In the case of some product chains, key data were not available through processors.

Production chain calculator
An Excel spreadsheet-based ‘calculator’ was developed to organise data, and facilitate the estimation of GHG emissions associated with various steps in each product chain.

Elements common to all product chain calculators included fields describing basic product characteristics including:

- sources;
- modes of production and transport;
- yield rates of intermediate and final products, and
- destinations of associated processing co-products; and
- intermediate and final product forms.

Fields for quantifying GHG emissions associated with key steps in the production chain were identified, including those associated with:

- capture or culture of raw materials;
- pre and post processing transport of materials by various modes (e.g. truck, ship, air freight);
- refrigeration throughout the product chain;
- non-refrigeration related processing; and
- packaging activities.

‘Life-cycle GHG’ emissions
In order to best reflect total ‘life-cycle’ GHG emissions, and standardise activity-specific emissions throughout the product calculators, emission intensities for various generic activities were developed, including:

- production and combustion of diesel, gasoline, natural gas, etc.;
- transport via three sizes of truck (3.6 tonne delivery vans, 16 tonne lorries and tractor trailers), ocean freighter, and air freight (both short haul and long haul);
- freezing (via both plate and blast freezing technologies); and
- refrigeration in storage/buildings, on trucks and in containers.

These were derived from various sources and applied, as appropriate, in each calculator. Where possible/appropriate, data reflecting contemporary European conditions were used.

Boats and gear
Due to the challenges inherent in acquiring real-world data regarding material and energy inputs, and resulting emissions associated with building and maintaining fishing boats and providing fishing gear, etc., a simplifying assumption was employed in each product chain calculator that models a fishery-derived product. In these cases, it was assumed that energy inputs to provide boats and gear would amount to 10% of the direct fuel energy
inputs to the fishery. Furthermore, resulting emissions were conservatively estimated to be based entirely on the combustion of natural gas.

**Calculating total GHG emissions associated with each product chain**

To facilitate the calculation and comparison of total GHG emissions associated with each product chain, all emissions were quantified in terms of their CO\textsubscript{2} equivalents, on the basis of their relative radiative forcing potential over a 100-year time horizon. Similarly, all inputs and resulting GHG emissions were quantified based on an output of one metric tonne of consumer-ready product, excluding the mass of any associated packaging materials, ice, etc. Consequently, for each product chain, results were expressed as kilograms of CO\textsubscript{2}-equivalent GHG emissions per tonne of finished seafood product.

Currently, there is no set procedure for how we should report the final CO\textsubscript{2} equivalent emissions figures. The possible expressions are:

- per tonne of final product;
- per tonne live-weight;
- allocating emissions to all utilised co-products; and
- allocating emissions entirely to primary seafood products.

**Emission burdens assigned to co-products**

The method by which emissions are assigned to co-products of processing activities, (e.g. fillets vs. processing trimmings rendered for fishmeal and oil) can, in some cases, have an important impact on the results. The method used was to consistently assign emission burdens up to the point of processing, to utilised co-products in proportion to the relative mass of the co-products involved. Emission burdens, however, were not assigned to true wastes destined for disposal, incineration, etc. This mass-based allocation rule is consistent with the carbon accounting practice recommended by the Carbon Trust in their preliminary assessment of emission accounting methods to use.

**Carbon Footprint Measurement Methodology (CFMM)**

The methodology is largely consistent with the Carbon Footprint Measurement Methodology (CFMM) Version 1.3, recently published by the Carbon Trust (2007), including initial process mapping with key stakeholders, data collection and validation, and carbon footprint calculation per process stage. All CO\textsubscript{2} equivalents are calculated according to 100-year GWP using IPCC assessment methods. Our mass-based allocation approach adheres to ISO 14041 guidelines, as well as CFMM recommendations. Two departures from CFMM methodology that should be noted are:

1. No account was made for GHG emissions associated with packaging for all product forms, or disposal-related emissions.
2. GHG emission estimates associated with the provision and maintenance of fishing vessels and gear were included.
Appendix C: Detailed case studies: CO$_2$ and economic profiles

For each case study, supply chain data was collected on costs, transport methods, product formats and yields, use of refrigeration and freezing, temperature-controlled storage, waste production, packaging, water use and effluent production. The results of the data collection were used to estimate GHG impacts and costs. The detailed information for each case study is included in this section.

**Case study 1 – Trawl-caught Icelandic haddock (Melanogrammus aeglefinus) sold to UK restaurant**

**Description of case study chain**

Supply of haddock to UK markets is sourced both internationally and domestically (from the UK fishing fleet). UK markets for haddock include retail and foodservice sectors. In retail, where outlets range from large retailers through to specialist fishmongers, product range formats include coated frozen, natural chilled and smoked chilled products. In foodservice, where outlets range from ‘white cloth’ restaurants, through to pub chains and mid-tier restaurants and fish and chip shops, haddock is sold in similar product format as in the retail sector, but also includes natural frozen fillets.

This case study describes a notional supply chain for haddock sourced from an Iceland fishing vessel, transported to the UK by container ship, and then processed for onward sale into UK restaurants.

On a weekly basis, an Icelandic trawler vessel catches haddock off the south coast of Iceland. After gutting on board the vessel, the material (at yield 84%) is landed as chilled head-on gutted fish in Icelandic port of Vestmannaeyjar on a Wednesday/Thursday. The material is then transferred to a chilled container and transported by container ship to Immingham in the UK, landing on the following Sunday/Monday. The containers are then dispatched by truck to Grimsby market where they are sorted, graded and sold to local processors. Having purchased some haddock, a local processor then transports the material by refrigerated van to the processing facility in Grimsby where the fish is then headed and filleted. Typical yield for fillets of haddock is 42% of landed weight, and typically the remaining 58% of the material is redirected to salted/dried markets in Africa or fishmeal. The haddock fillets are then transported by refrigerated van to a regional outlet (fishmonger, restaurant or fish and chip shop).
**Figure 40:** Supply chain for Icelandic fresh haddock to UK for sale in a restaurant; notional product, co-product and waste share of total volume and revenue

**Figure 41:** Notional GHG emissions profile for Icelandic fresh haddock
Table 38: Icelandic haddock; profile for volumes, revenues and GHG emissions

<table>
<thead>
<tr>
<th>Activity</th>
<th>Stage</th>
<th>Yield (%)</th>
<th>Product</th>
<th>Co-products</th>
<th>Waste</th>
<th>GHG emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Volume</td>
<td>Revenue</td>
<td>Volume</td>
<td>Revenue</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kg of fish</td>
<td>£</td>
<td>Kg of fish</td>
<td>£</td>
</tr>
<tr>
<td>Final product</td>
<td></td>
<td>100</td>
<td>1,000</td>
<td>22,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Final storage refrigeration</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Refrigeration losses</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>Truck to customer</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Storage</td>
<td>100</td>
<td>1,000</td>
<td>9,540</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Processing refrigeration</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-refrigeration</td>
<td>Processing</td>
<td>42</td>
<td>2,381</td>
<td>4,286</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>Truck to processor</td>
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<td>2,381</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>Container transport</td>
<td>100</td>
<td>2,381</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>Truck to Container</td>
<td>100</td>
<td>2,381</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Storage</td>
<td>100</td>
<td>2,381</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>All truck refrigeration</td>
<td>100</td>
<td>2,381</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Catching refrigeration</td>
<td>100</td>
<td>2,381</td>
<td>2,262</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Primary production</td>
<td>Catching and landing</td>
<td>84</td>
<td>2,834</td>
<td>0</td>
<td>0</td>
<td>454</td>
</tr>
</tbody>
</table>

*GHG emissions per tonne final product (kg CO₂e).

Background notes and assumptions:

- Assumed to be derived from haddock (*Melanogrammus aeglefinus*) caught in the North Atlantic.
- Harvested by Icelandic trawlers off the south coast of Iceland.
- Fish gutted at sea (~16% of live weight is disposed of at sea).
- Skinless fillets represent 42% of landed weight.
- Landed in Iceland, refrigerated and stored on ice, container to UK for processing.
- All processing trimmings generated on land are utilised (destined for fishmeal or African markets).
Case study 2 – Trawl-caught smoked mackerel (Scomber scombrus) sold to UK multiple retailers

Description of case study chain
Supply of mackerel to UK markets is sourced domestically from UK fishing fleet landings and also from imports, which generally consist of foreign vessels landing their catch in the UK. UK markets for mackerel include retail and foodservice sectors. In retail, outlets range from small specialist fishmongers to large multiple retailers, and the product range includes smoked products and natural chilled products.

This case study describes a notional supply chain for mackerel sourced from a UK fishing vessel, and processed for sale in a UK multiple retailer.

During the mackerel season (November - January) pelagic trawlers catch mackerel in the waters around the UK, particularly in the North Sea and the north east Atlantic Ocean. The catch is then landed into one of the few pelagic factories situated in the North East of Scotland or in Shetland. When the material is landed at a pelagic processing factory, it is typically pumped straight from the vessel into the processing operation. At this stage it will undergo a process of grading, to sort the fish by size, and then blast freezing to bring the material down to a temperature at which it can be stored. The seasonal nature of the mackerel fishery means that it is necessary to freeze large amounts of the material, in order to allow supplies to be available for consumers all year round.

After freezing, the material remains in cold storage until it is required for further processing. At this stage it is brought out of the cold store and defrosted. It is then filleted either by hand or by machine. Hand filleting provides slightly higher yields than machine filleting, and larger mackerel will also give a larger yield. In this example, a machine-filleted mackerel is used, giving a 45% yield. The remaining 55% is utilised as co-products, either as pet food or fishmeal. The fillets are then ready for smoking, which involves four main steps: brining, hot smoking, removal from the kiln and packing. The overall output yield in this process is 75% of the input volume of fillets. The loss of mass during this process is largely due to moisture released during the smoking process; however, there is an average of 3% waste at the packing stage, which will be sold for fishmeal.

The smoked mackerel fillets are then distributed by refrigerated lorry to UK multiple retailer distribution hubs.

Figure 42: Supply chain for mackerel smoked fillet for sale in retail; notional product, co-product and waste share of total volume and revenue
Figure 43: Notional GHG emissions profile for mackerel smoked fillet
Table 39: Smoked mackerel fillet; profile for volumes, revenues and GHG emissions

<table>
<thead>
<tr>
<th>Activity</th>
<th>Stage</th>
<th>Yield (%)</th>
<th>Product Volume (Kg of fish)</th>
<th>Product Revenue (£)</th>
<th>Co-products Volume (Kg of fish)</th>
<th>Co-products Revenue (£)</th>
<th>Waste Volume (Kg of fish)</th>
<th>Waste Revenue (£)</th>
<th>GHG emissions Stages</th>
<th>Cumulative (kg CO₂ eq./t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final product</td>
<td></td>
<td>100</td>
<td>1,000</td>
<td>7,850</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>960</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Refrigeration losses</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>960</td>
</tr>
<tr>
<td>Transportation</td>
<td>Truck to customer</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>227</td>
<td>954</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Storage</td>
<td>100</td>
<td>1,000</td>
<td>5,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>728</td>
</tr>
<tr>
<td>Non-refrigeration</td>
<td>Processing/repackaging</td>
<td>97</td>
<td>1,031</td>
<td>0</td>
<td>31</td>
<td>0.31</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>721</td>
</tr>
<tr>
<td>Non-refrigeration</td>
<td>Processing smoking</td>
<td>75</td>
<td>1,375</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>344</td>
<td>0</td>
<td>220</td>
<td>721</td>
</tr>
<tr>
<td>Non-refrigeration</td>
<td>Processing</td>
<td>45</td>
<td>3,055</td>
<td>1,680</td>
<td>67</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>501</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Storage</td>
<td>100</td>
<td>3,055</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>501</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Processing refrigeration</td>
<td>100</td>
<td>3,055</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>495</td>
</tr>
<tr>
<td>Transportation</td>
<td>Truck to processor</td>
<td>100</td>
<td>3,055</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>466</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>All truck refrigeration</td>
<td>100</td>
<td>3,055</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>456</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Catching refrigeration</td>
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<td>3,055</td>
<td>2,749</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>454</td>
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<td>Primary production</td>
<td>Catching and landing</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>445</td>
<td>445</td>
</tr>
</tbody>
</table>

*GHG emissions per tonne final product (kg CO₂ e)

Background notes and assumptions:

- Assumed to be derived from Atlantic mackerel (*Scomber scombrus*) caught in the North Atlantic.
- Harvested by pelagic trawl vessels.
- Fish landed whole, then frozen in storage.
- Fillets represent 45% of landed weight.
- Landed in UK, transported to processor before freezing and subsequent processing.
- All processing trimmings generated on land are utilised (destined for pet food or fishmeal).
Case study 3 - Farmed Atlantic salmon (Salmo salar) sold as fresh fillets to UK multiple retailers

Description of case study chain
Supply of Atlantic salmon in the UK is predominantly sourced from salmon farms domestically, but can also be sourced internationally from countries such as Norway or Chile. Salmon is a popular species for consumption in the UK, and is sold though both retail and foodservice sectors. It is sold in many different formats, including ambient (canned), fresh/chilled and frozen formats. In retail, salmon is sold in specialist fishmongers and large multiple retailers. In the foodservice sector, it is sold in many different types of foodservice establishment from high quality 'white cloth' restaurants to low cost canteen style dining, and everywhere in between.

This case study describes a notional supply chain for chilled salmon fillets which are sourced from a UK salmon farm, are processed in Scotland, and are sold to a multiple retailer.

The supply chain for farmed Atlantic salmon fillets is relatively uncomplicated. The salmon are reared at a salmon farm, and once harvested they are gutted at the farm, giving a yield of 90%. The material (head on gutted salmon) is then transported by refrigerated truck to a processor in Scotland. The processor then turns the head on gutted salmon into fillets, and the yield at this stage is 63% of the gutted weight. The waste at this stage in the process is the head, which is disposed of, and the rack, which is utilised for fish meal. It is estimated that around 15% of the live weight of salmon is waste, which is utilised for co-products. After filleting, the products are refrigerated and transported by truck to UK retail distribution hubs.

Figure 44: Supply chain for Scottish farmed salmon fillets in retail; notional product, co-product and waste share of total volume and revenue
Figure 45: Notional GHG emissions profile for salmon fillet
Table 40: Salmon fillet; profile for volumes, revenues and GHG emissions

<table>
<thead>
<tr>
<th>Activity</th>
<th>Stage</th>
<th>Yield (%)</th>
<th>Product</th>
<th>Co-products</th>
<th>Waste</th>
<th>GHG emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Volume</td>
<td>Revenue</td>
<td>Volume</td>
<td>Revenue</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kg of fish</td>
<td>£</td>
<td>Kg of fish</td>
<td>£</td>
</tr>
<tr>
<td></td>
<td>Final product</td>
<td>100</td>
<td>1,000</td>
<td>12,920</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Refrigeration losses</td>
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<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>Truck to customer</td>
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<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Storage</td>
<td>100</td>
<td>1,000</td>
<td>9,190</td>
<td>238</td>
<td>7</td>
</tr>
<tr>
<td>Non-refrigeration</td>
<td>Processing/packaging</td>
<td>63</td>
<td>1,587</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>All transport refrigeration</td>
<td>100</td>
<td>1,587</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>Ship transport</td>
<td>100</td>
<td>1,587</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>Truck transport</td>
<td>100</td>
<td>1,587</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Primary production</td>
<td>On farm activities</td>
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<tr>
<td>Primary production</td>
<td>Salmon feed provision</td>
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<td>1,764</td>
<td>0</td>
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<td>0</td>
</tr>
</tbody>
</table>

*GHG emissions per tonne final product (kg CO₂e)

Background notes and assumptions:

- Assumed to be derived from Atlantic salmon (*Salmo salar*) farmed in Scotland.
- Farmed salmon derived from numerous sites around Scotland.
- Upon harvesting, fish are gutted yielding ~90% carcass to live weight.
- Transported fresh by truck to processor.
- Processing yields 63% fillet mass from gutted weight.
- Assume 15% of carcass weight is used for co-products, remainder to landfill.
- Transported fresh by truck to customer.
Case study 4- Pot/creel-caught brown crabs (Cancerus pagurus) sold to UK outlets

Description of case study chain
Supply of crab to UK markets is sourced domestically from the UK fishing fleet and also from imports. The UK market for crab products is varied. Products include whole/live, cooked/whole crab, cooked white meat only, cooked crab claws, dressed crab, as well as other value added products. In the UK, crab is supplied to wholesale outlets and retail, both independent fishmongers and multiple retailers, in any of these formats. However, a large proportion of crab is exported. Live crabs are largely exported to France and Spain, but they may then be further transported to other countries in the EU.

This case study describes a notional supply chain for crab sourced from a UK fishing vessel, and processed into a white-meat only product for sale in a UK multiple retailer.

Crabs are landed in the UK as whole, live animals. They are typically caught in static fishing gear by vessels going to sea for 1-2 days. Live crabs are maintained either at cool temperatures, often receiving no refrigeration on board, or they are held in vivier tanks. These are large tanks of recirculated, refrigerated water into which the live crabs are placed and maintained alive.

After landing, the crabs are directly transported to a processor by live transport (vivier) truck or refrigerated van. At the processor they are kept alive until they are cooked in a continuous process within two days of receipt. After cooking, the crabs are rapidly chilled and processed to separate the edible portion from the shell (30-40% yield of edible portion). The edible portion consists of white and brown meat.

The cooked, chilled crab meat is packaged and maintained as a chilled product. The packs are despatched from the processor in a refrigerated van to UK based wholesale or retail outlets.

Waste from the process includes viscera and shell, both of which are unavoidable wastes. The waste is disposed of to a landfill site. The brown meat and other edible products from the crab are classed as co-products for the purposes of this case study.
Figure 46: Supply chain for white crab meat for sale in retail; Notional product, co-product and waste share of total volume and revenue

Figure 47: Notional GHG emissions profile for white crab meat
### Table 41: White crab meat; profile for volumes, revenues and GHG emissions

<table>
<thead>
<tr>
<th>Activity</th>
<th>Stage</th>
<th>Yield (%)</th>
<th>Product</th>
<th>Co-products</th>
<th>Waste</th>
<th>GHG emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Volume</td>
<td>Revenue</td>
<td>Volume</td>
<td>Cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kg of fish</td>
<td>£</td>
<td>Kg of fish</td>
<td>£</td>
</tr>
<tr>
<td>Final product</td>
<td></td>
<td>100</td>
<td>1,000</td>
<td>37,580</td>
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<td>0</td>
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<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td></td>
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</tr>
<tr>
<td>Transportation</td>
<td>Truck to customer</td>
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<td>18,000</td>
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<tr>
<td>Non-refrigeration</td>
<td>Processing/packaging</td>
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<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
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<td>Non-refrigeration</td>
<td>Processing/cooking</td>
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<td>3,667</td>
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<td>Storage</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Processing refrigeration</td>
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<td>13,333</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>Refrigeration</td>
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<td>13,333</td>
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<td>0</td>
</tr>
<tr>
<td>Primary production</td>
<td>Catching and landing</td>
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<td>13,333</td>
<td>15,333</td>
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<td>0</td>
</tr>
<tr>
<td>Primary production</td>
<td>Catching refrigeration</td>
<td>100</td>
<td>13,333</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*GHG emissions per tonne final product (kg CO₂e)*

Background notes and assumptions:

- Assumed to be derived from Brown crab (*Cancerus pagurus*) caught in UK waters.
- Harvested by UK potters and creelers operating off UK coast.
- White crab meat represents 7.5% of landed weight.
- Landed in UK as live animals on vivier trucks for processing.
- After processing, 65% of landed weight goes to landfill, remaining trimmings generated on land are utilised (as dressed crab or frozen crab meat).
**Case study 5 - Dredged king scallops (Pecten maximus) sold to UK outlets**

**Description of case study chain**

Supply of scallops to UK markets is sourced domestically from the UK fishing fleet and also from imports. The UK market for scallops is varied. Products largely include shucked (roe on or off) scallop meat, but also a variety of value-added products. In the UK, scallops are supplied to wholesale outlets and retail, both independent fishmongers and multiple retailers, in any of these formats. However, a large proportion of scallop landings are exported. Live scallops may also be sold to UK-based markets, but this is on a small scale.

This case study describes a notional supply chain for scallops sourced from a UK fishing vessel and shucked into a roe-on scallop meat-only product for sale in a UK multiple retailer.

Scallops are landed in the UK as whole, live animals. They are typically caught in a dredge by vessels going to sea for up to 3 days. Live scallops are maintained at cool temperatures, often receiving no refrigeration on board.

After landing, the scallops are directly transported to a processor, where they are shucked within one day of receipt. Shucking is the process of separating the edible portion from the shell (20% yield of edible portion).

After shucking the scallops are chilled and packaged. They are despatched from the processor in a refrigerated van to UK-based wholesale or retail outlets.

Waste from the process includes viscera and shell, both of which are unavoidable wastes. A significant proportion of curved shell is cleaned and sold (exported) so it can be used to present shucked scallop meat at point of retail. The flat shell waste is treated and used for other purposes, whereas the viscera (non-edible flesh) are disposed of to an AD facility.

**Figure 48:** Supply chain for scallop meat for sale in retail; notional product, co-product and waste share of total volume and revenue
Figure 49: Notional GHG emissions profile for scallop meat
Table 42: Scallop meat; profile for volumes, revenues and GHG emissions

<table>
<thead>
<tr>
<th>Activity</th>
<th>Stage</th>
<th>Yield (%)</th>
<th>Products (Volume &amp; Revenue)</th>
<th>Co-products (Volume &amp; Revenue)</th>
<th>Waste (Volume &amp; Cost)</th>
<th>GHG emissions (kg CO₂ eq./t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kg of fish</td>
<td>£</td>
<td>Kg of fish</td>
<td>£</td>
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<tr>
<td>Final product</td>
<td></td>
<td>100</td>
<td>1,000</td>
<td>15,770</td>
<td>0</td>
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<td>Refrigeration</td>
<td>Final storage refrigeration</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Refrigeration losses</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
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<td>1,000</td>
<td>8,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-refrigeration</td>
<td>Storage</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-refrigeration</td>
<td>Processing/repackaging</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>Non-refrigeration</td>
<td>Processing</td>
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<td>5,000</td>
<td>0</td>
<td>3,000</td>
<td>120</td>
</tr>
<tr>
<td>Transportation</td>
<td>Truck to processor</td>
<td>100</td>
<td>5,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>All truck refrigeration</td>
<td>100</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Primary production</td>
<td>Catching and landing</td>
<td>100</td>
<td>5,000</td>
<td>9,500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Primary production</td>
<td>Catching refrigeration</td>
<td>100</td>
<td>5,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*GHG emissions per tonne final product (kg CO₂e)

Background notes and assumptions:

- Assumed to be derived from Scallop (*Pecten maximus*) caught in UK waters.
- Harvested by UK scallop dredge operating off UK coast.
- Scallop meat represents 20% of landed weight.
- Landed in UK as live animals transported by truck for processing.
- After processing, 20% of landed weight goes to landfill, remaining 60% are utilised as co-products.
Case study 6 - Pot/creel-caught whelks (Buccinum undatum) sold to UK outlets

Description of case study chain
Supply of whelk to UK markets is sourced domestically from the UK fishing fleet. The UK market for whelk is largely as a cooked and shucked product (i.e. removed from the shell). In the UK, cooked whelk is supplied to wholesale outlets and retail (both independent fishmongers and multiple retailers) in chilled or frozen form. However, a large proportion of cooked, frozen whelk is exported, particularly to Korea.

This case study describes a notional supply chain for whelks sourced from a UK fishing vessel, cooked, frozen and supplied to a UK based wholesaler.

Whelks are landed in the UK as whole, live animals. They are typically caught in static fishing gear by vessels going to sea for 1-2 days. Live whelks are maintained in refrigerated holds on board the vessel.

After landing, the whelks are directly transported to a processor in a refrigerated van. At the processor they are cooked in a batch process within one day of receipt. Cooking facilitates separation of the edible portion from the shell (20% yield of edible portion). After cooking the whelks are frozen.

The cooked, frozen whelks are packaged and maintained as a frozen product. They are despatched from the processor in a refrigerated van (held at frozen storage temperatures) to UK-based wholesale or retail outlets.

Waste from the process includes viscera and shell, both of which are unavoidable wastes. The shell waste and viscera (non-edible flesh) are disposed of.

Figure 50: Supply Chain for whelk meat for sale in retail; notional product, co-product and waste share of total volume and revenue.
Figure 51: Notional GHG emissions profile for whelk meat
### Table 43: Whelk meat; profile for volumes, revenues and GHG emissions

<table>
<thead>
<tr>
<th>Activity</th>
<th>Stage</th>
<th>Yield (%)</th>
<th>Product</th>
<th>Co-products</th>
<th>Waste</th>
<th>GHG emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kg of fish</td>
<td>£</td>
<td>Kg of fish</td>
<td>£</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Volume</td>
<td>Net revenue</td>
<td>Volume</td>
<td>Net revenue</td>
</tr>
<tr>
<td>Final product</td>
<td></td>
<td>100</td>
<td>1,000</td>
<td>14,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Refrigeration losses</td>
<td>100</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>Truck to customer</td>
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<td>3,750</td>
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</tr>
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<td>Storage</td>
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<td>1,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-refrigeration</td>
<td>Processing cooking</td>
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<td>5,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>Truck to processor</td>
<td>100</td>
<td>5,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>All truck refrigeration</td>
<td>100</td>
<td>5,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Catching refrigeration</td>
<td>100</td>
<td>5,000</td>
<td>3,500</td>
<td>0</td>
<td>0</td>
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<td>Catching and landing</td>
<td>100</td>
<td>5,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*GHG emissions per tonne final product (kg CO₂eq)*

**Background notes and assumptions:**

- Assumed to be derived from Whelk (*Buccinum undatum*) caught in UK waters.
- Harvested by UK potters and creelers operating off UK coast.
- Whelk meat represents 20% of landed weight.
- Landed in UK as live animals transported by truck for processing.
- After processing, 80% of landed weight goes for disposal.
Case study 7 – Trawl-caught Nephrops
(Nephrops norvegicus) sold to EU outlets as frozen, whole animals

Description of case study chain
Supply of nephrops to UK markets is sourced domestically from the UK fishing fleet. The UK market for nephrops is largely as the product scampi, which is the breaded tail meat. In the UK, scampi is supplied to wholesale outlets and retail (both independent fishmongers and multiple retailers) primarily in frozen form. However, a large proportion of whole nephrops is exported. Live nephrops, in particular, are largely exported to France and Spain, but they may then be further transported to other countries in the EU.

This case study describes a notional supply chain for nephrops sourced from a UK fishing vessel and frozen as a whole product for export to France.

Nephrops are landed in the UK as tails, whole (dead) or whole (live) animals. They are typically caught in a trawl by vessels going to sea for up to 5 days, or in a pot/creel by vessels going to sea for 1-2 days. Trawl-caught nephrops are typically landed as tails or whole (dead), whereas pot/creel-caught nephrops are typically landed whole (live). Live nephrops are maintained in seawater at cool temperatures on board, receiving no refrigeration. Whole (dead) nephrops or tails are often iced on board, and then held in refrigerated storage until landing. However, some smaller-sized vessels may not use either ice or refrigeration.

After landing, nephrops are sold under contract and directly transported to a processor where they are size graded before freezing. They are packed in plastic trays with a plastic film lid and cardboard outer sleeve. The product is then frozen and packed into cardboard transit packaging before being held in cold storage.

The nephrops are removed from frozen storage, and packed into an articulated lorry, ensuring cold storage temperatures are maintained. They are transported by road to wholesalers in France.

As the nephrops are maintained whole, there is no waste related to the production of the product. However, 5% of the throughput is not of sufficient standard, i.e. the nephrops are damaged. These damaged nephrops are used in another process for the production of scampi.
Figure 52: Supply Chain for whole nephrops for sale in wholesale; notional product, co-product and waste share of total volume and revenue.

Figure 53: Notional GHG emissions profile for whole nephrops wholesale
**Table 44:** Wholesale of whole Nephrops; profile for volumes, revenues and GHG emissions

<table>
<thead>
<tr>
<th>Activity</th>
<th>Stage</th>
<th>Yield (%)</th>
<th>Product</th>
<th>Co-products</th>
<th>Waste</th>
<th>GHG emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Volume</td>
<td>Revenue</td>
<td>Volume</td>
<td>Cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kg of fish</td>
<td>£</td>
<td>Kg of fish</td>
<td>£</td>
</tr>
<tr>
<td></td>
<td>Final product</td>
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<td>0</td>
</tr>
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<td></td>
<td>Refrigeration losses</td>
<td>100</td>
<td>1,000</td>
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<td></td>
<td>Transportation</td>
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<td>0</td>
</tr>
<tr>
<td></td>
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<td>1,000</td>
<td>10,000</td>
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<td>0</td>
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<tr>
<td></td>
<td>Refrigeration Processing/Packaging</td>
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<td>1,000</td>
<td>0</td>
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<td>0</td>
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<td>Non-refrigeration Processing/Packaging</td>
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<td>1,053</td>
<td>0</td>
<td>53</td>
<td>316</td>
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<tr>
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<td>Refrigeration All truck refrigeration</td>
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<td>Refrigeration Catching refrigeration</td>
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<td>Primary production Catching and landing</td>
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<td>1,053</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*GHG emissions per tonne final product (kg CO₂e)*

Background notes and assumptions:

- Assumed to be derived from Nephrops (*Nephrops norvegicus*) caught in UK waters.
- Harvested by Nephrops trawl.
- Landed whole in the UK.
- Transported to processor by truck.
- Product represents 95% of landed weight.
- Assumed that all processing trimmings are utilized.
Table 45: GHG emissions from different stages of food product life cycle during retail (kgCO₂e/t)
Taken from Greenhouse Gas Impacts of Food Retailing, Brunel University, Defra funded project FO405, October 2008.³⁹

<table>
<thead>
<tr>
<th>Food Component</th>
<th>38 tonne articulated vehicle</th>
<th>Landfill without recovery</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>RDC¹</td>
<td>Transport²</td>
<td>Refrig display cabinets³</td>
</tr>
<tr>
<td>Chilled foods</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packed fresh meat</td>
<td>0.1</td>
<td>14.9</td>
<td>199.7</td>
</tr>
<tr>
<td>Ready meals</td>
<td>0.1</td>
<td>14.9</td>
<td>495.9</td>
</tr>
<tr>
<td>Cheese</td>
<td>0.038</td>
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<td>270.7</td>
</tr>
<tr>
<td>Beef cottage pie</td>
<td>0.1</td>
<td>14.9</td>
<td>204.1</td>
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<tr>
<td>Frozen foods</td>
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<td></td>
</tr>
<tr>
<td>Frozen peas</td>
<td>0</td>
<td>16.2</td>
<td>567.4</td>
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<tr>
<td>Frozen potatoes</td>
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<td>14.3</td>
<td>319.7</td>
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</table>

1 – Regional refrigerated distribution centre
2 – Truck engine plus refrigeration (Total return distance with a single drop is 190km – vehicle empty during return journey with refrigeration system off
3 - Cabinet energy only
4 - Cabinet refrigerant leakage only
5 – Energy plus refrigerant leakage
6 – heating, ventilation and air conditioning
9.0 References

1. WRAP; Household Food & Drink Waste in the UK, November 2009.
3. The Seafish Guide to Discards, Seafish, 2009
8. Seafish 2009, Trade Summaries
9. Nielsen epos data on UK Seafood Retail, 2009
10. CREST data on foodservice sector, Seafish
11. Seafood Industry Value Chain Analysis (Cod, Haddock & Nephrops), Seafish, 2003
12. UK Value Chain and price forecasts for Cold Water Prawns, Seafish 2005
18. Regulation (EC) No 1774/2002; European Animal By-Products Regulations
19. Animal By-Products Regulations 2005, UK.
22. Context Report, Retail epos data total GB coverage to 26/12/2009 (compiled by Nielsen)
25. Waste Arisings in the supply of Food and Drink to households in the UK, WRAP project no RSC002-005.
28. Seafish, Fish Box Trials Fact Sheet 2007
29. 'Fishing for EPS'; NISP Yorkshire & Humber Case Study
31. Guidance for Fish processors on Water and Effluent Minimisation, Seafish, 1999
34. Cleaner Production Assessment in Fish Processing, United Nations Environment Programme
35. Division of Technology, Industry and Economics. 2000
36. SINTEF (2009) Carbon Footprint and energy use of Norwegian seafood products
www.wrap.org.uk/retail