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Environmental Effects of Fish on the Consumers Dish

- Life Cycle Assessment of Icelandic Frozen Cod Products -

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<tr><td>Ágrip á íslensku:</td><td colspan="3">Markmið verkefnisins var að skilgreina nýtingarmöguleika og takmarkanir vistferilgreiningar með tillit til:
▪ mats á umhverfisáhrifum þorsks
▪ umhverfismerkinga
▪ umhverfishæfrar vöruþróunar.

Vistferilgreining er ung aðferðafræði í stöðugri þróun. Helstu takmarkanir hennar er að hún tekur ekki tillit til alla umhverfisþátta, eins og t.d. áhrif veiða á sjávarbotn eða vistkerfið, áhrif frákasts og áhrif veiða á tiltekinna tegunda á aðrar tegundir. Þessar takmarkanir leiða til nokkurs vanmats á umhverfisáhrifum þorskveiða og jafnvel ofmats á áhrifum olíunotkunar við veiðarnar.

Niðurstöður verkefnisins sýna á ótvíræðan hátt að vistferilgreining sýnir hvar í ferlinum helst er hægt að ná fram umhverfislegum ávinningi í formi vöruþróunar, með breytingum á vinnsluferli, flutningum o.s.frv.
Helstu niðurstöður eru:
• Umhverfisáhrif af völdum olíunotkunar við fiskveiðar og flutninga yfirgnæfa önnur umhverfisáhrif
• Olíunotkun fiskiskipa er mest við veiðarnar og meðferð veiðarfæra um borð. Allt að 70% af olíunotkuninni fer í þessa þætti.
• Að meðaltali nota fullvinnsluskip 0.65 L af olíu til að veiða 1 kg af þorski sem samsvarar rúmlega 400 g af þorskflökum.
• Upplýsingar um alla efna- og orkunotkun þorskafurða frá vöggu til grafar

Vistferilgreining er gott tæki fyrir iðnaðinn að nota til að meta hvar helstu umhverfisáhrifin verða í ferli vörunnar. Það þarf að einfalda aðferðina og er unnið að því. Vistferilgreining er einnig mikilvæg þegar verið er að skilgreina umhverfismerkta vöru.</td></tr>
<tr><td>Lykilorð á íslensku:</td><td colspan="3">Þorskur, vistferilgreining, umhverfisáhrif , fullvinnsluskip</td></tr>
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Summary in English:

The aim of this project was to examine the viability and limitations of LCA with respect to:

- Evaluation of environmental impacts of cod production.
- Environmental labelling.
- Eco friendly product development.
- Streamlining LCA for SME´s .

Since LCA methodology is not yet advanced enough to evaluate some factors, such as the use of seafloor, effects on stock and ecosystems, the relevance of oil might be overestimated. These limitations do cause some underestimation of the environmental impacts of fisheries. A way to advance the method with regards to these factors would be to establish a group of scientists, including LCA specialists, ecologists and ichthyologists. Such a group could make use of the available data to make them comparable.

The results of this project demonstrate that LCA methodology can be used to indicate where the greatest environmental gains can be expected in the production chain.
The main results were:

- The greatest environmental impact was traced to the oil consumption during the fishery phase.
- Great part of the oil consumption is used to operate the fishing gear and that accounts for more than 70% of the total oil consumption in a fishing trip.
- To catch 1 kg of cod 0,65 L on average oil was needed which gives approximately 400 g of fish fillets when served on the consumer's dish.
- Data for material-and energy usage for cod products from cradle to grave

LCA is a useful decision making tool for the industry to monitor the environmental impacts in a production chain. The method needs simplification and work is being done to simplify the method and make it more user friendly. LCA has also been found useful when defining the criteria for eco-labelling.

English keywords: *LCA ,cod, environmental effects, processing trawlers*

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1. INTRODUCTION

Environmental affairs have been gaining momentum in the last few decades, with increased public awareness that natural resources are not inexhaustible and that nature has therefore to be treated with respect. To begin with most of the focus was air pollution, concerns about the disposal of radioactive waste etc, but in recent years sustainable development has become equally important. For example, there is a growing interest among consumers about what they eat and how their food is produced. Consequently, there is an increasing pressure on the food industry as a whole, not only to produce quality products but also to be able to demonstrate that their production does not affect the environment adversely.

The purpose of this study is to assess the environmental impacts of cod products that are processed on board a fishing processing trawler. One of the reasons for the choice of this product is that quick frozen seafood products have constituted about 50% of the value of seafood exports from Iceland for many years.

The project was financed by; the Ministry of Fisheries, the Research Council of Iceland, Icelandic Fisheries Laboratories and Technological Institute of Iceland.

2. FISHERIES AND ENVIRONMENT IN ICELAND

2.1 Fisheries management system in Iceland

The Fisheries Management Act of 1990 is the cornerstone of the present fisheries management system in Iceland. By this Act, the system of individual transferable quotas (ITQ) was established for the fisheries. Other important management tools are e.g. fishing gear regulations (to protect small fish) and long term and temporary closure of fishing grounds (to protect important breeding/spawning grounds). In the year 2001, there were 23 species involved in the ITQ system and they represent almost 97% of the total catch value. All catches by Icelandic vessels within the exclusive fishing zone must be landed, weighed and recorded in accordance with Icelandic law and regulations. The Directorate of Fisheries gathers data concerning catches from landing declarations and declarations of purchase and dispositions of raw material. Trawlers that process their catch on board are required to check their yield factor at certain intervals, and keep samples thereof which are specially marked. At the end of each fishing trip a report is sent to the Directorate of Fisheries containing information on the catch, the processed products and the average yield during the trip.

2.2 By-catch and discards

Various definitions of by-catch and discards are found in the literature, making it somewhat difficult to compare studies in this field. A workshop held in 1992 to sort out this problem came up with definitions of the terms for by-catch and discards (McCaughran, 1992), and those definitions are used in this study, see table1.

Table 1. Definition of terms for by-catch and discards (McCaughran, 1992)

Term	**Definition**
Target catch	The catch of a species or species assemblage which is primarily sought in a fishery
By-catch	Discarded catch plus incidental catch
Discard rate	The proportion to the total catch, which is discarded. Rates may be computed for individual species or combined groups of species
Discard mortality rate	The proportion of the discarded catch that dies as a result of catching or handling processes
Discard mortality	Discard mortality rate multiplied by the discarded catch

Discard is of special concern for environmental evaluation of fisheries. A part of the discarded fish does not survive and the energy and resources needed to take the fish onboard is not utilized effectively.

2.3 Effects on seafloor and biodiversity

The effects of sweeping the sea bottom by trawling have been a cause for concern in recent years. In Icelandic waters, most trawling for cod takes place in deep waters, i.e. depths between 100 and 500 m (Ragnarsson and Steingrímsson, in preparation).

Sweeping of the bottom over long time is considered to rout up sediment, crush life forms and other forms and alter the type of sediment and the landscape of the bottom. Direct mortality of fauna and damages of habitats occurs in the swept areas (Auster et al., 1996), causing alterations of the composition of benthic communities. The extent of the damage depends on the type of bottom, fragility of the area and the benthic communities in question, which again depends on the depth of the water, since deep sea fauna is characterised by fragile forms (Fosså et al., 2000).

Biodiversity and the ecosystem of the sea and the food web are considered to be under direct and indirect stress and under continuous change due to trawling activities (Jennings and Kaiser, 1998). The swept area undergoes some changes of landscape towards uniformity, the results being fewer hiding places for the remaining cod growing up there and, as mentioned before, it damages and changes the communities in question, possibly causing less feed for the remaining cod. Some of the potential stress factors caused by trawling are listed here.

- Direct damage to benthic fauna, in correlation with mean depth and size of the swept area.
- Direct changes in landscape towards uniformity possibly causing less hiding grounds for the remaining growing cod.
- Direct and indirect changes to the communities in question possibly causing less feed for the remaining cod.
- Direct removal of cod, the predator of many other species, possibly giving other predators the opportunity of taking their hunting grounds over and expand their stocks.
- Direct and indirect effects on cod, other species and species interactions caused by discards of dead fish and weak escape fish with low life expectancies which does thus become feed for scavengers, some of which are also predators, thus possibly amplifying already favourable situation for such predators.
- Direct removal of older and bigger individuals, causing stress on the cods stock sustainability and recovery.

These factors are causing concern and it will be informative to watch researches and results in this area.

2.4 Environmental management systems and eco-labelling

The Icelandic minister of fisheries has a declaration of environmental policy, which is divided into four categories (see appendix 1):

- Conservation and sustainable utilisation of the live marine resources in Icelandic waters
- Fishing in international waters
- Pollution and effluents
- Trade

Each category has its own objective that aim at fishing, handling, energy use etc. The declaration seeks to affirm the government's commitment regarding environmental issues. Companies working in fisheries have expressed the same kind of interest and some have even issued their own environmental policy. Such a policy can be seen as the first step in an environmental management system (EMS) and one might expect that the policy will be followed by a structured EMS with environmental planning, including measurable objectives and targets, training and operational control in the years to come (ISO, EN ISO 14001996, 1996).

It could be useful for these companies to have a way to communicate with consumers on their environmental preferences. Eco-labelling and EMS are an alternative for companies to inform consumers and customers. They give consumers the ability to reduce the environmental impacts of their daily activities by purchasing environmentally preferable products and minimizing their effects on the environment during use and disposal. Labels thus give consumers the ability to vote their preferences in the marketplace and therefore potentially shift the market towards products that minimize environmental impacts. To perform this eco-labels and EMS should be based as much as possible on the best available scientific information on the environmental impacts and the best available technology at any given time and take necessary precautions to ensure sustainability of natural resources. This means that the consumer has to be assured that the labelled fish products derive from stocks that are harvested in a sustainable way and that the fishing process is such that the effects on the ecosystem are minimized by the use of the best available technology.

The report “Environmental Labelling Issues, Policies and Practices Worldwide,1998" gives an overview on the different types of environmental labels. Another report, “An Arrangement for the Voluntary Certification of Products of Sustainable Fishing, 2000", gives good indications on the criteria which environmental labels for fisheries should contain to obtain sustainability of stocks. According to the report the criteria should insist on a fisheries management plan with regular scientific advice and pre-agreed management action when precautionary reference points are reached. It is also necessary to have an efficient monitoring and control system. Destructive fishing practices are not to be allowed, discards should be minimal and ecosystem issues should be considered.

2.5 Fuel consumption and emissions

In recent years increasing emphasis has been put on environmental issues in Iceland. Signing the Kyoto-declaration made it imperative to seek new ways to reduce the emission of greenhouse gases to the atmosphere. Fuel consumption is one factor that has great effects on greenhouse gas emission and CO_2 is about 83% of the exhaust of greenhouse gases in Iceland. Figure 1 shows the origin of total release of CO_2 in Iceland in the year 2000, where fishing ships are emitting 26 % of the total CO_2 emissions in Iceland.

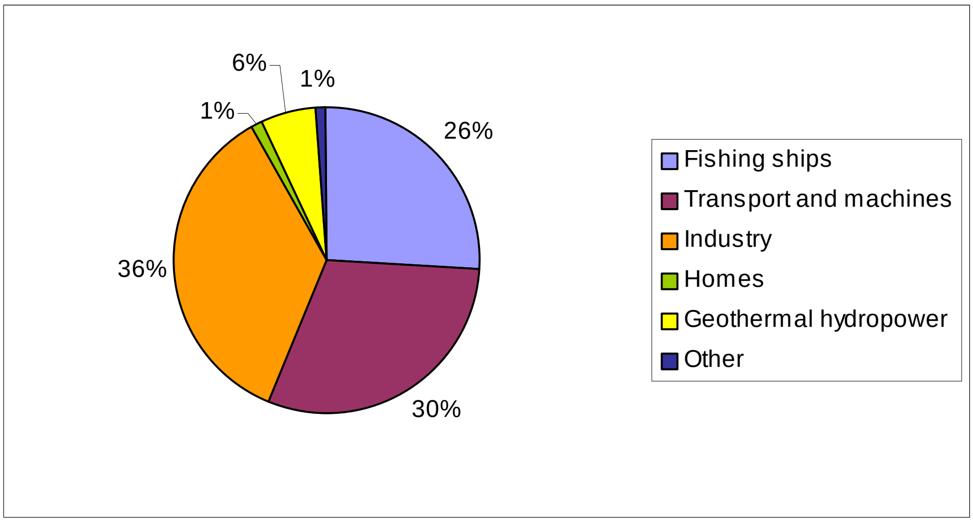


Figure 1. Total release of CO_2 according to source in Iceland 2000 (www.hollver.is)

The price of fuel greatly influences energy use and attempts to minimize the use of energy as well. When the price is low there is less motivation to save energy or to find new energy sources. High energy prices, on the other hand, encourage energy saving actions that include investment in new energy saving equipment or usage of new energy sources. In the year 2000, the total oil consumption in Iceland was about 860.000 tons. Thereof the fishing ships used 28,4% (244.000 tons) and other ships 9,2% (79.000 tons). Therefore, a big part of the release of CO_2 in the atmosphere in Iceland can be traced to the oil consumption of ships (Yngvadóttir and Arason., 2001). It is clear that great economic and environmental profits can be gained by reducing the oil consumption. The fuel consumption in Iceland has increased during the last years. This increase has on the average been 2% per year since 1983 (Ragnarsson, 2001). Figure 2 shows the fuel consumption in Iceland in the year 2000 divided on different trade (Vilhjálmsson, 2001).

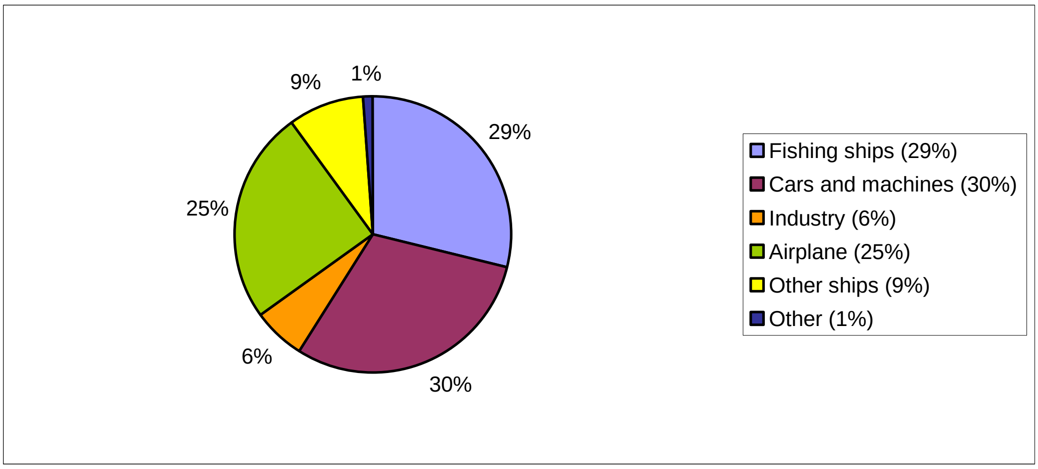


Figure 2. Fuel consumption in Iceland the year 2000 after trade

The fishing fleet in Iceland, using 29% of fuel as shown in figure 2, consists of a variety of ships, e.g. trawlers, processing trawlers, fishing vessels, seiners and small boats. These ships and boats have different energy needs, see table 2 for information from earlier studies.

Table 2. Fuel consumption for different types of ships in 1997 (Rúnarsson, 2001).

	Fuel consumption (litres fuel/ kg fish)
Processing trawlers	0,71
Trawlers	0,43
Vessels>10 tons	0,21
Boats<10tons	0,15
Seiner (herring, capelin)	0,035
Seiner (blue whiting)	0,089

2.6 Use of chemicals

A variety of chemicals are used in the fish and transport industry, such as coolants, cleaning agents, additives in machinery and paint. Anti-fouling paints have been a major concern for more than a decade. For more than 30 years, for example, TBT has been used as an active chemical for anti-fouling purposes. TBT is persistent, resulting in a rising concentration in sediments, ecosystems, especially in harbours and inland seas. TBT is an effective anti-fouling agent used in boat paint, but has proven to leach out to the environment and have deleterious effects on non-target marine organism. TBT has chronic toxic effects at extremely low concentrations. (Skarphéðinsdóttir, 2002)

In Iceland a ban on TBT has been in force since 1990. The ban was though, not total since some exemptions were allowed in the legislation. The use has become more stringent through the years and today the ban is issued in regulation nr. 619/2000. The exemption for the use of TBT is valid for processing trawlers. This ban is in accordance with the directive 76/769/EBE. The use of TBT has decreased rapidly over the last years in Iceland. Today the most commonly used paint for both trawlers and cargo ships is a copper containing free association anti-fouling paint. Copper is also toxic and can be one of the most poisonous heavy metals if present in excess in a bio accessible form. Copper affects sensitive organisms, especially in areas near harbours or near waters used for the deposition of dredge material from harbours (Madsen et al., 1999). Some countries have expressed concern about the use of copper-based anti-fouling paint and the use of it is already limited on pleasure crafts in the Netherlands. Whether this will change the use of anti-fouling agents in the future remains to be seen.

2.7 Processing trawler

Figure 3. Processing trawlers

The processing trawlers use otter board, which can be grouped into two groups:

- Bottom trawls
- Pelagic trawls (midwater-trawl)

Bottom trawls are used to catch flatfish and demersal catch with the exception of ocean redfish. This study is limited to processing trawlers using bottom trawls to catch demersal catch (main catch: cod, haddock, saithe, redfish, catfish) and flatfish catch (main catch: halibut, Greenland halibut, plaice). Information on the processing trawlers that were used to obtain data in this study is summarised in table 3.

Table 3. Information about the processing trawlers in the fishing fleet in Iceland used in this study.

Number of processing trawlers	Size in gross tonnage	Power of main engine, kW	Total Quantity of catch (tonnes)	Total value thous. ISK
25	800-2000	1500-3700	131.733	14.792.526

2.8 Fishing gear

Bottom trawls are used to fish on or right above the seafloor and pelagic trawl is used to fish in the midwater or well above the seafloor. Cod, for example, is caught by using bottom trawling gear, as well haddock, saithe and halibut. The bottom trawl consists of net, otter boards or doors, ground cable or sweep line and headline with floats. The trawl net is a large bag made of netting. It is drawn along the seafloor to scoop up the fish at or near the bottom, see figure 4. The net has the shape of a large bag, wide at one end, the mouth, which is open, leading to the body of the net, which tapers to the closed end. Fish that enter through the mouth are trapped in the codend. To keep the mouth vertically open a headline with a fixed number of floats is used at the upper edge of the mouth and at the lower edge of the mouth a weighted ground rope or foot rope is used. Horizontal spread of the mouth is attained by otter boards or doors towed ahead of the net. The otter board can have different shapes, such as rectangular, oval or V shape and are made of steel or wood. Bottom trawls are often towed for several hours at a time and over large areas, but midwater trawls are towed for 10 to 20 minutes.

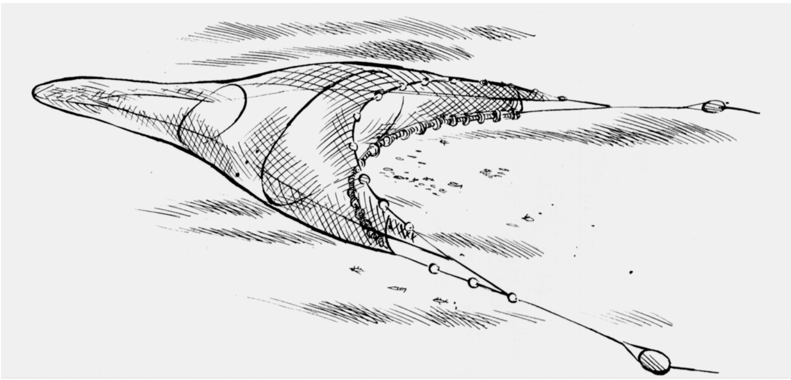


Figure 4. The bottom trawl

3. GENERAL DESCRIPTION OF THE LCA METHODOLOGY

3.1 The LCA methodology

Life cycle assessment is a method for evaluating the environmental aspects associated with a product during its entire life cycle. The results of LCA studies can be used for different applications, e.g. to evaluate the environmental impact of a single product, product comparison, product improvement, support for strategic choices, benchmarking and external communication. The LCA is a relatively young technique and the results of a LCA study need to be interpreted carefully. A LCA study consists of four steps:

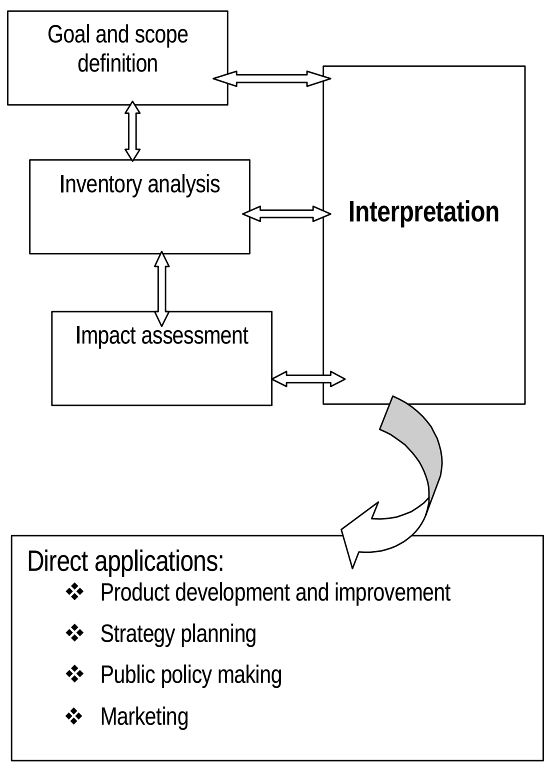
- Goal and scope definition.
- Inventory analysis. Detailed data collection on input and output of material, energy and other resources for the production, use and disposal.

- Impact assessment. Understanding the environmental relevance of the in-and outputs.
- Interpretation.

Figure 5 show these different steps in a schematic way. The first part describes why the study is being conducted and that is the guide on how detailed the study shall be and how it will be presented. The scope of the study includes the functional unit (the unit to be studied), reference flow and the boundaries.

The main purpose of an inventory analysis, in the context of data collection, is to identify and quantify the relevant input and output flows over the whole life cycle of a product. The following are considered to be inputs and outputs.

- Input: The use of resources, land, raw materials, fabricated products, auxiliary materials, energy carriers and electricity during the manufacturing, use and disposal or recycling of the product.
- Output: Emissions to air, water and land, as well as waste and by-products.



Life Cycle Assessment framework. Ideology for LCA based on the ISO standard 14040.

At the start a functional unit is defined and the boundaries for the study are set. Detailed information is collected on the quantity of material, energy and other resources required for the production, use and disposal of the product. Then the impact from the whole process is evaluated: the impact assessment. Lastly an interpretation has to be carried out where the results are laid out in common terms. The figure identifies the reciprocal influences of the individual phases. The application and the framework of the LCA have been purposely separated. An application is not automatically given through the results of an LCA study.

Figure 5. Schematic picture of the important parts in an LCA-analyse

It may be necessary to allocate product system when dealing with multiple products (e.g. by-catches and mixed fisheries). It is therefore important to define a key to allocate the environmental burdens of the production to the individual products according to their proportional effects.

The standard ISO 14042 divides the phases of the impact assessment into mandatory and optional elements. Mandatory are the impact categories, classification and characterisation and optional are normalisation and weighing of the impacts. An LCA can be thought of as following a few steps:

Step 1. Impact Assessment

a) Impact categories chosen; such as, carcinogenic, respiratory organics, respiratory inorganic, climate change, land use, minerals and fossil fuels.
b) Classification; Inventory data assigned to impact categories.
c) Characterisation; The substances that contribute to impact categories are multiplied with a characterisation factor that expresses the relative contribution of the substance. As an example, for global warming potential (GWP) CO_2 contribution is set to one and CH_4 is multiplied with 21, as it is 21 times more affective as a greenhouse gas than CO_2.

Step 2. Normalisation

The impact categories are divided by a reference, giving the impact categories the same unit and making it easier to compare them.

Step 3. Weighing

Evaluation of the importance of impact categories.

Step 4. Interpretation and evaluation

Interpretation and evaluation is made from the results in step 1 to step 3 and from the inventory analysis.. Recommendations can be established on these as long as the quality of data is acknowledged and uncertainties made clear. It should be noted that only step 1 is mandatory

Another important point is the transparency of LCA results. The standard ISO 14043 comprises three interpretation elements:

- Identification of significant issues;

- Evaluation which considers completeness, sensitivity to assumptions and consistency checks;
- Conclusions, recommendations and reporting of the significant issues.

The methods available for impact assessment are aimed at effects on land and fresh water. No method includes effects on fish stocks or effects on the seafloor. These categories are discussed in a separate chapter and for the numerical analysis the emphasis is on finding a method that takes into account the other categories. The method selected for the impact assessments is Eco-Indicator 99 (Goedkoop and Spriensma, 1999).

3.2 Impact assessment method

In the Eco-Indicator 99 method, the results of the impact assessment are given in Eco-Indicator point (Pt) or the unit milli-point (mPt), which is a dimensionless figure. The absolute value of the points is not very relevant since the main purpose is, on one hand, to compare relative differences between different stages in the life cycle and, on the other hand, to compare environmental impact categories. The scale is chosen in such a way that the value of 1000 Pt is representative for a yearly environmental load of one average European inhabitant. So the figures are calculated from comprehensive studies on the environmental load of use of resources, fate of chemicals, land use, etc.

3.3 SimaPro

The software employed for this LCA is SimaPro 5, by Pré Consultants, Amersfoort, The Netherlands. The software is designed to perform Life Cycle Assessments. The user builds up his own life cycle with his own data. The software contains databases with inventory data for different processes, such as production of a diversity of materials, transporting of goods by different means and models for several means of disposal. This data is divided into databases depending on the origin of the inventory data. There is a certain consistence for the data within each database as the boundary conditions are set for the database as a whole. It is therefore recommended to use data from the same origin if possible. Still, this is not always possible as all the processes needed may not be available within one database. In this study data from

BUWALL,(1990, 1994, 1996, 1998) and ETH-EHS databases (1996) were chosen if possible.

4. GOALS AND SCOPE

4.1 Goal

The aim of this project was to define the usability and limitations of LCA with respect to:

- Evaluation of environmental impacts of cod production.
- Environmental labelling.
- Eco friendly product development
- Streamlining LCA for small and medium sized enterprises.

4.2 System boundaries

The choice of the system boundaries is of vital importance for the LCA-study because it has to encapsulate the whole life cycle of the product. The system boundaries follow the fish from "cradle to grave." In this study, it starts when the ship leaves the harbour in Iceland and ends on the consumers dish in a fish and chip´s restaurant in England, see figure 6. Consumables used for steaming, fishing, processing and transport are included but the materials used to build the fishing vessel, transport vessel etc. are not included. The life cycle is in several steps:

1. The ship leaves the harbour (steaming, fishing and processing the catch).
2. Fish is landed on the deck.
3. Fish is transported on land and sea and stored in freezing containers.
4. The consumer is served fish and chips in a restaurant in England.

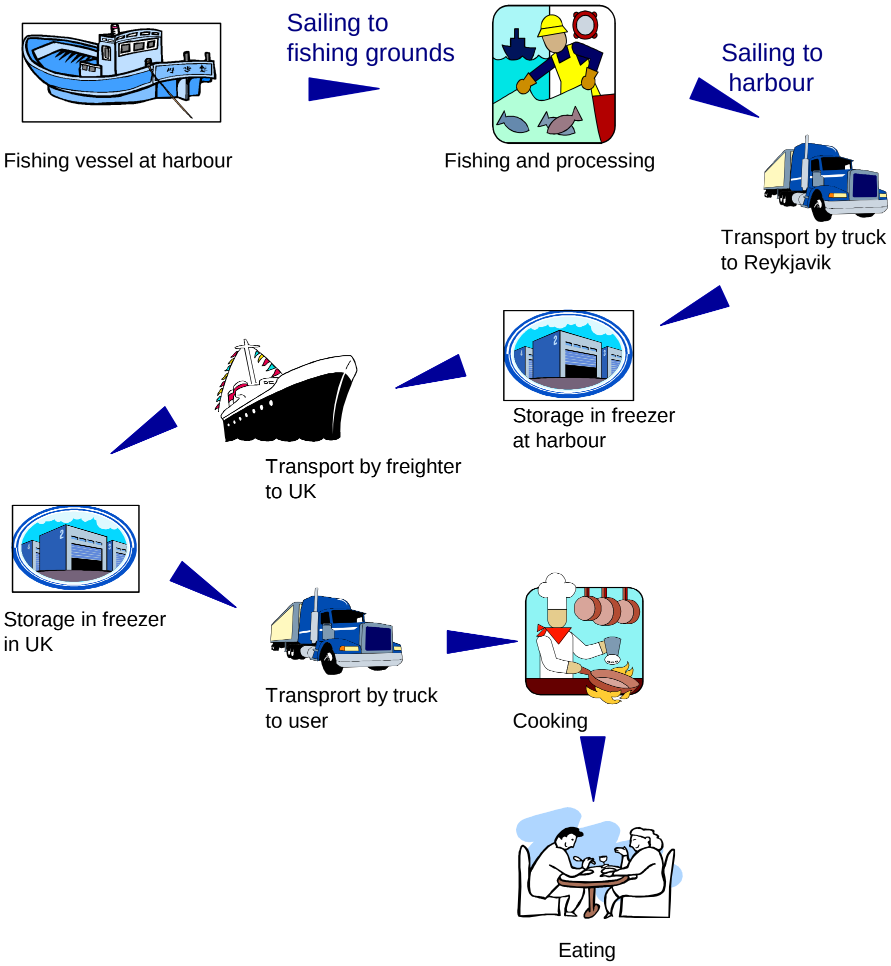


Figure 6. System boundaries for the product, 9 kg cod fillets skinless with bones.

This study is limited to processing trawlers using bottom trawls to catch demersal roundfish catch (main catch: cod, haddock, saithe, redfish, catfish exception ocean redfish) and demersal flatfish catch (main catch: halibut, Greenland halibut, plaice). Mixed catch is here defined as demersal catch without ocean redfish, together with flatfish catch. In addition, the production and disposal of fishing gear, anti-fouling agents, packaging and fuel production is taken into account.

4.3 Functional unit

The functional unit has been chosen 9 kg frozen cod fillet package, which is a valuable product and important for the Icelandic economy. The fish is caught by Icelandic processing trawlers (size 800-2000 GRT) using bottom trawl. The product is a skinless fillet with bones, processed and packed on board the processing trawlers.

4.4 System description

LCA is a methodology which evaluates the environmental impacts of a product or a production system from cradle to grave, so to speak. All phases of the life cycle are considered to be of equal importance to begin with, e.g. transport of goods and disposal of packaging is equally important as the production and use of the product itself. In this study, the life cycle starts when the ship leaves the harbour and heads to the fishing grounds. The fish is caught, processed and frozen onboard. The product is a package of 9 kg frozen skinless cod fillets with bones. The yield is around 41-45 %. The guts are returned to sea and the rest of the gutted fish is used in various products, like fish mince and dried heads. Figure 7 shows the estimated mass allocation for landed cod and the utilisation for different by products. The figures are taken from yield reports from the Directorate of Fisheries and several reports (Árnason et al., 1994), (Ríkharðsson, 1992), (Birgisson and Eyjólfsdóttir, 1997) and (Birgisson and Þorsteinsson, 1997) .

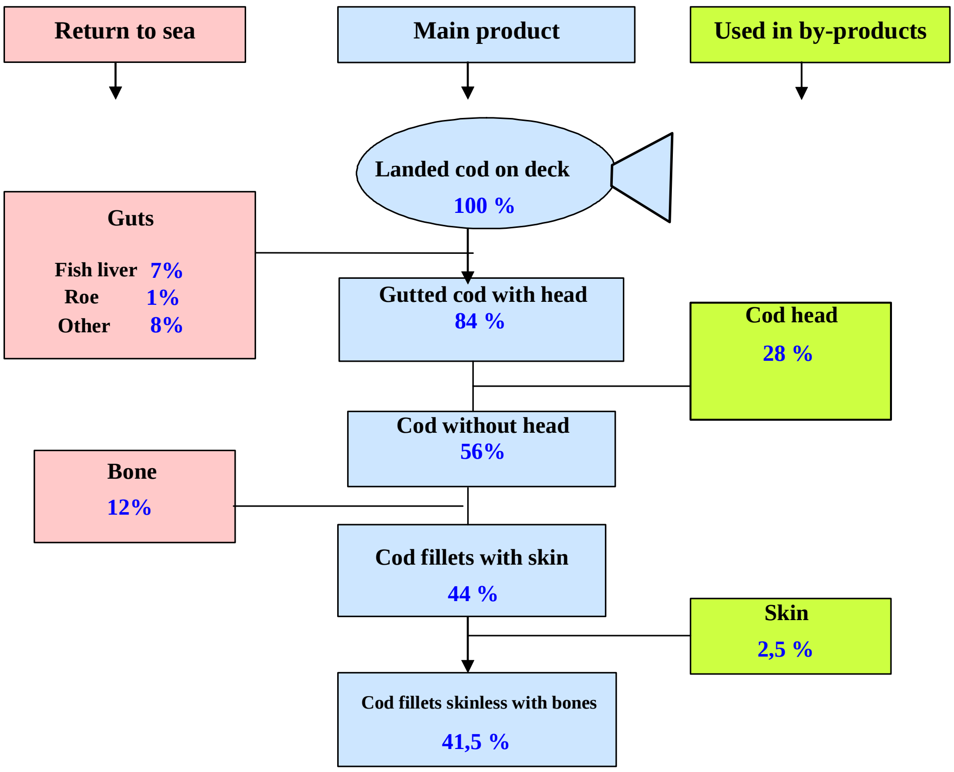


Figure 7. Yield of cod on deck and the utilisation for several by products.

The frozen product is landed at various ports in Iceland, packed in containers and transported by trucks to Reykjavik, where, after approximately twenty days in freezer storage, it is transported by a cargo ship to England. The product is unloaded and stored for approximately four days in a freezer storage in England. Finally, the product is transported by a delivery van to its final destination, a fish and chips restaurant, where it is fried and served with chips. As customary in LCA approaches, the capital goods are not taken into account, such as the ship itself, cars, roads, houses etc. It has been shown that capital goods have only a minor effect on the whole life cycle of products (Ziegler, 2001). Important input and output materials are considered those that are either used in a great amount, such as oil, or materials causing special concern, such as anti-fouling- and cooling agents. In figure 8, a schematic view of the process is given along with relevant material and energy for in and outputs.

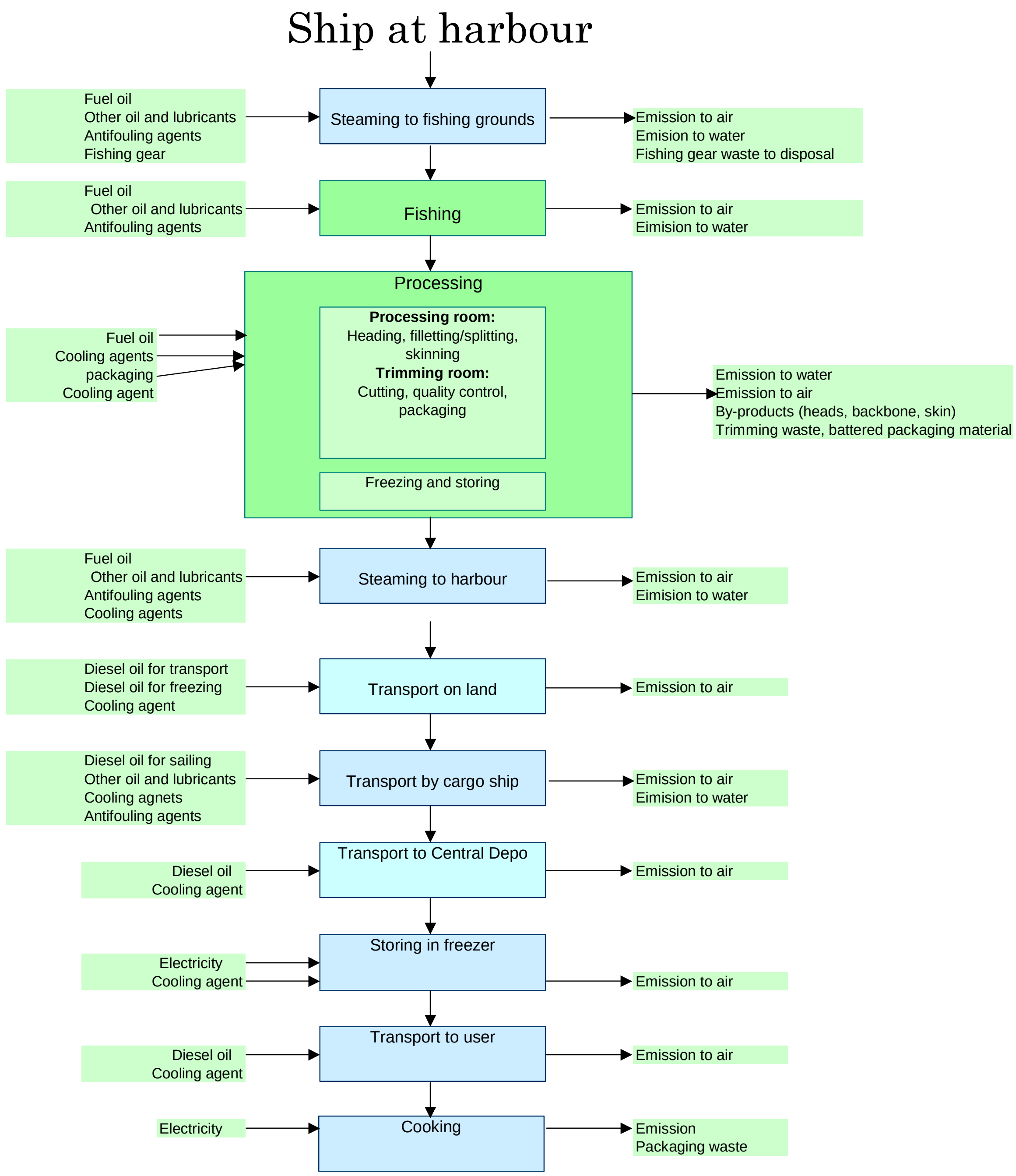


Figure 8. Description of the production system for frozen cod fillets caught and processed onboard fishing processing trawler

5. INVENTORY ANALYSIS

5.1 Inventory analysis

The information collected in this study was based on data for the year 2000. A compiled list for data collection, assumptions and description of individual phases of the life cycle is given in appendix II.

The average fuel consumption per kg of mixed catch for processing trawlers using bottom trawl was calculated by using data gathered from the Directorate of Fisheries, fishing companies, oil consumption reports and by interviewing specialists in this field. Mixed catch is here defined as demersal catch with the exception of ocean redfish, together with flatfish catch. The data does not give the opportunity to separate the fuel consumption needed for catching cod from the fuel consumption needed to catch other species using bottom trawls. Therefore, the oil consumption is calculated by using the total mixed catch for the processing trawlers using bottom trawls. The files used for modelling are from BUWALL database available in the SimaPro software. Adaptions were made to these files according to detailed Icelandic information available and obtained from several sources.

Information about the fishing gear was gathered from users, a fishing gear manufacturer and a municipal waste disposal company. Modelling of the anti-fouling agent was based on information from a paint manufacturer, both concerning composition of the paint and the amount needed. Double-checking of the information by approaching different parties gave same results. Data on copper is taken from a Delft University file and the end of life is modelled as emission to water. In order to get an estimation of the importance of guts and bones returned to sea these were modelled as nitrogen emissions and it proved to have minor effects.

The files used for transport by land and sea are from the BUWALL database. These files are based on a LCA for transport, total aggregated system, including production of fuel. Adaptations were made to these files according to the detailed information available in this study on fuel consumption and load. In addition, the use of chemicals in the transport chain was taken into account. Detailed information was obtained on the transport in Iceland and in cargo ships, with good information for the type of truck, fuel, load, storage-time and so forth. The data from the UK is more of an estimation as the variation of routes is substantial and it was decided to use average figures giving an indication of an average journey that the fish block travels.

The packaging consists of a box with plastic sheets as interlayer. The primary packaging is put three and three together in secondary packaging, a corrugated cardboard box, and wrapped with plastic strings.

End of life scenario for a 9 kg sea frozen cod fillets block is assumed to be at a fish-and-chip restaurant in England. The fish is cooked in a frying oil and then consumed with chips. Energy for cooking is included in the total life cycle, using data on average Electricity in Great Britain (BUWALL).

5.2 By-catch and discards

There were no direct measurements made on board the fishing vessel regarding by-catch and discards. Information was collected through various studies, mainly globally and one local study that was found. The main sources were the following: (ICES CM 2002/ACE:03), (Alverson et al., 1994) and (Pálsson et al., 2002).

5.3 Seafloor

The data for seafloor (total swept area, total number of hauls, total catch etc.) was obtained from the Marine Research Institute (MRI) and the Directorate of Fisheries databases. The MRI database contains registrations of all individual tows within the Icelandic territorial waters from 1991, to a spatial resolution of 1´(1 minute) latitude and 1´ (1 minute) longitude. Logbook data (mandatory for Icelandic vessels since 1991) on fishing effort of otter trawling for demersal fish were used for analysing data for magnitude of seafloor effect over the period 1991-1997, for vessels (> 2000 kW). (Ragnarsson and Steingrímsson, unpublished report).

5.4 Allocation methodology

The system under study produces several products. Not only do the trawlers bring cod ashore but other species as well. The environmental impacts of the fishing activities need to be allocated between these different products and there are several ways to do this. This can be done by performing mass allocation assuming that the effects are proportional to the mass of products or by economic allocation, assuming that the environmental impact should be allocated more heavily on the more valuable products. One would use economic allocation (Ziegler, 2001) where there is a big difference in the value of the main products and by-products, but where that is not the case one would choose mass allocation. Mass allocation is a less time dependent method because the TAC (Total Allowable Catch) for cod is decreasing the world over and the price fluctuates considerably with supply of fish. Still another way would be to avoid allocation by using mathematical model based on target and non-target species to calculate the proportion between cod and other species (Mattsson and Ziegler, in preparation).

According to the data used in this study, cod was 44% of the mass of fish brought ashore. The relative product value of this cod was 48 % of the total fishing value. There is therefore little difference between using mass and economic allocation in this case and mass allocation was performed.

6. RESULTS

The results presented in this chapter are both referring to the results of the numerical life cycle analysis of the product, chapter 6.1, and to particular aspects not included as numerical factors, chapter 6.2. The numerical analysis of the life cycle is based on LCA modelling in the software SimaPro.

6.1 LCA analysis

The life cycle of frozen cod products was modelled in the software SimaPro. The modelling was made by dividing the life cycle into smaller parts in order to compare the results from different operations. An overview of the whole life cycle is given in figure 9. The bars in the boxes show the relative environmental importance of each box, the bigger the bar the bigger is the environmental impact.

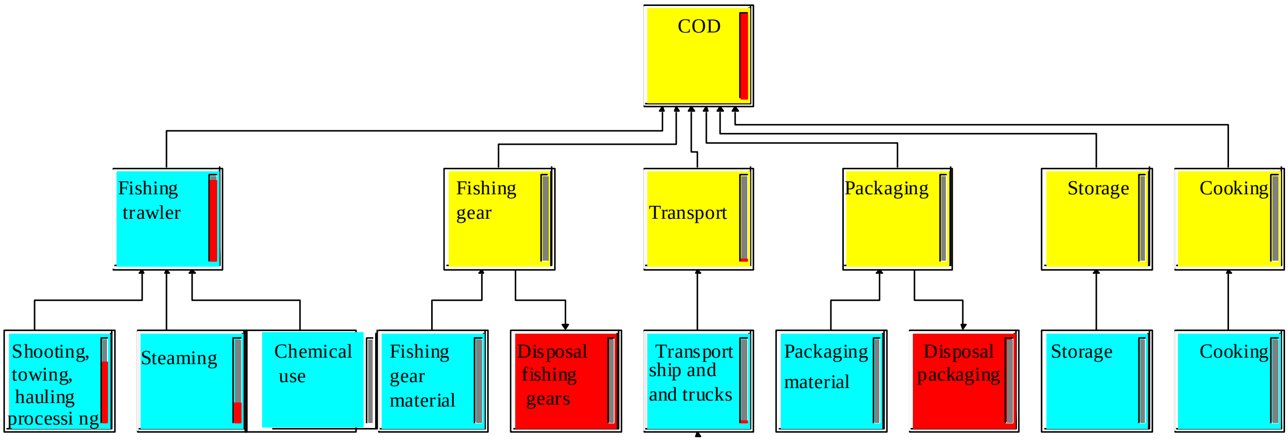


Figure 9. Process tree over the whole life cycle from cradle to grave

As mentioned in chapter 3, the first step in the evaluation of the environmental impacts is the choice of impact categories. Based on the system description the following impact categories are considered being of importance for cod fisheries:

- Effects on biodiversity*
- Effects on seafloor*
- Impact categories reflecting the use of fossil fuels; climate change, acidification, toxic effects on humans and ecosystems, depletion of fossil fuel and minerals
- Use of resources other than fossil fuel
- Toxic effects from biocides in paint
- Depletion of ozone layer due to refrigerating agents
- Impact categories reflecting land filling and incineration of waste; climate change, toxic effects on humans and ecosystem
- Land use (road, storage etc.)

Categories marked with a star,* are not included in the numerical study discussed in this chapter but are discussed separately in chapter 6.2.

6.1.1 Whole life cycle

Based on the preceding choice of impact categories, the characterisation for the overall life cycle was performed and the result is shown in figure 10.

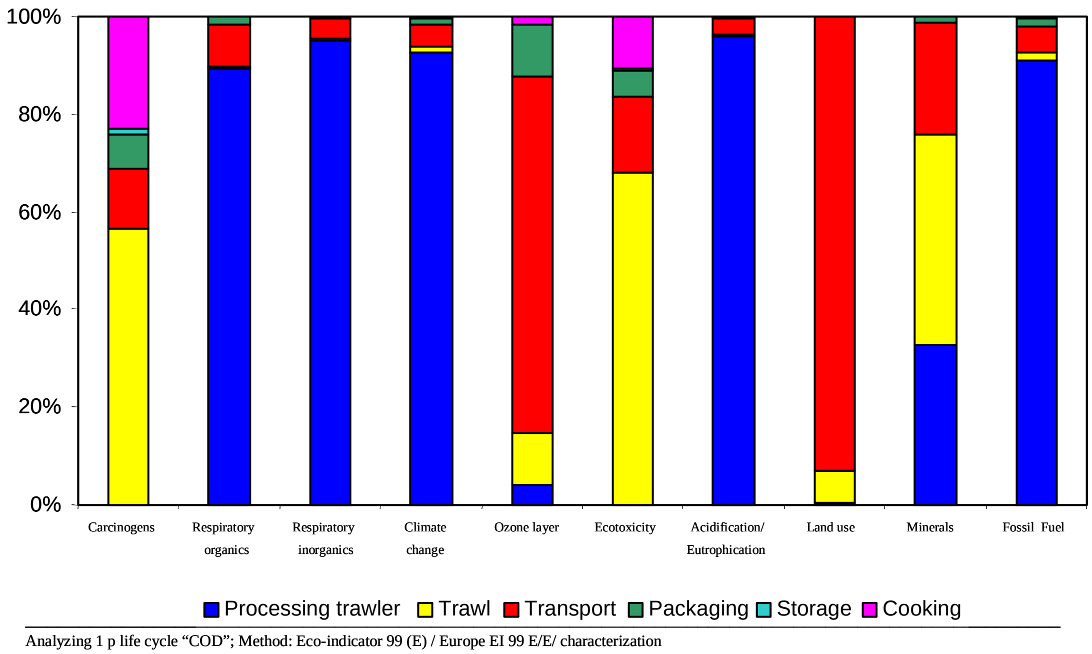
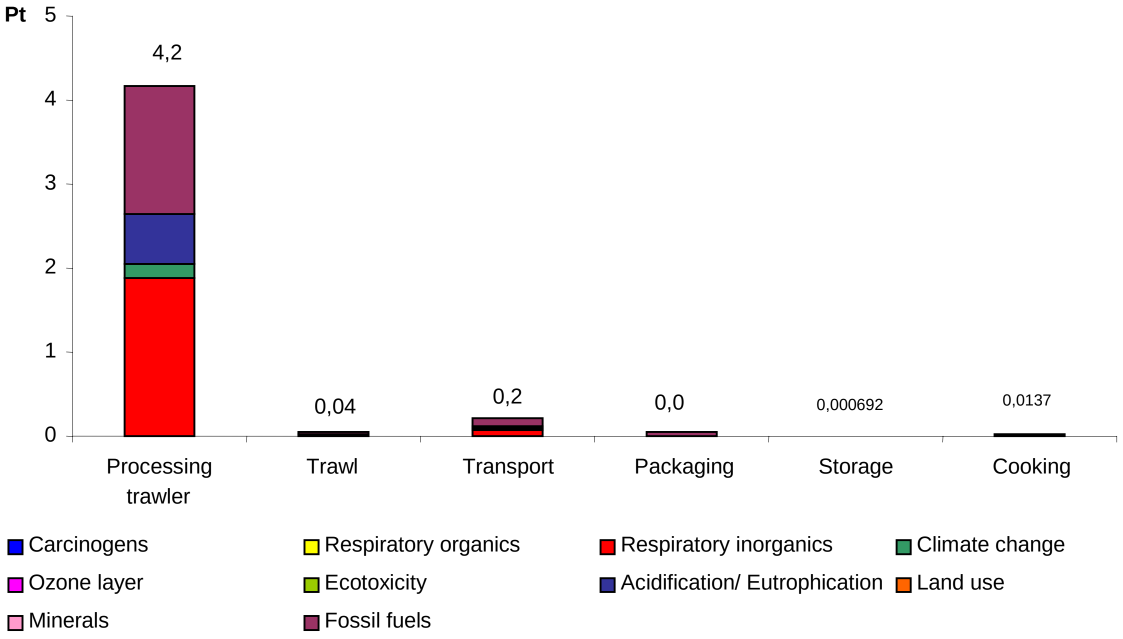


Figure 10. Relative contribution of the different phases of the life cycle of the product to environmental impact categorie, all categories are equivalent to 100%.

Looking at the product "from cradle to grave," the fishery, i.e. the processing trawler and the gear (shown in blue and yellow in figure 10), are the phases of the life cycle that contribute relatively most to almost all impact categories. These parts of the life cycle dominate the following categories; respiratory organics and inorganics, climate change, ecotoxicity, acidification and fossil fuels. The environmental impacts of a processing trawler can be related to the use of fossil fuels and hence to CO_2 emission, reported to cause climate change, as well as effects on respiratory system. It is noticeable that a processing trawler does not have any effect on the land use impact category since the method which is used for this study does only take into account traditional land use but not effects on marine ecosystem land use or seafloor effects. Transport of fish along with raw materials for fishing gear and disposal of fishing gear, however, dominate impact categories like ozone layer and ecotoxicity. Even though these categories appear to be of great importance, as seen in figure 10, the picture changes when one step is taken further in the LCA process. This is shown in figure 11 which shows the weighed contribution of the phases to environmental impact categories. All parts of the life cycle, including transport and fishing gear, are actually having minor impact compared to the vessel.

To better understand the difference between these two figures (10. and 11.), it is good to observe that even though figure 10 shows that transport dominates the land use impact category, the effects of transport is minor in the whole life cycle. It is also clear from figure 11 that the most important environmental effects are those connected with the processing trawler, which dominates all other parts of the life cycle.



Analyzing 1 p life cycle "COD"; Method: Eco-indicator 99 (E) / Europe EI 99 E/E/ single score

Figure 11. Weighed contribution of the different phases of the life cycle of the products to environmental impact categories.

6.1.2 Processing trawler

In order to analyse further the results for the processing trawler, the relative division of energy use for different operations in a processing trawler and activities during fishing with bottom trawl was figured out. Figure 12 shows the relative partitioning of energy use between different operations and activities during fishing with bottom trawl. The predominating activity is the towing of the fishing gear (63%), followed by steaming to and from fishing ground (16%). Operations not directly connected to sailing and fishing, that is processing of the catch, contribute 7% to the overall energy use.

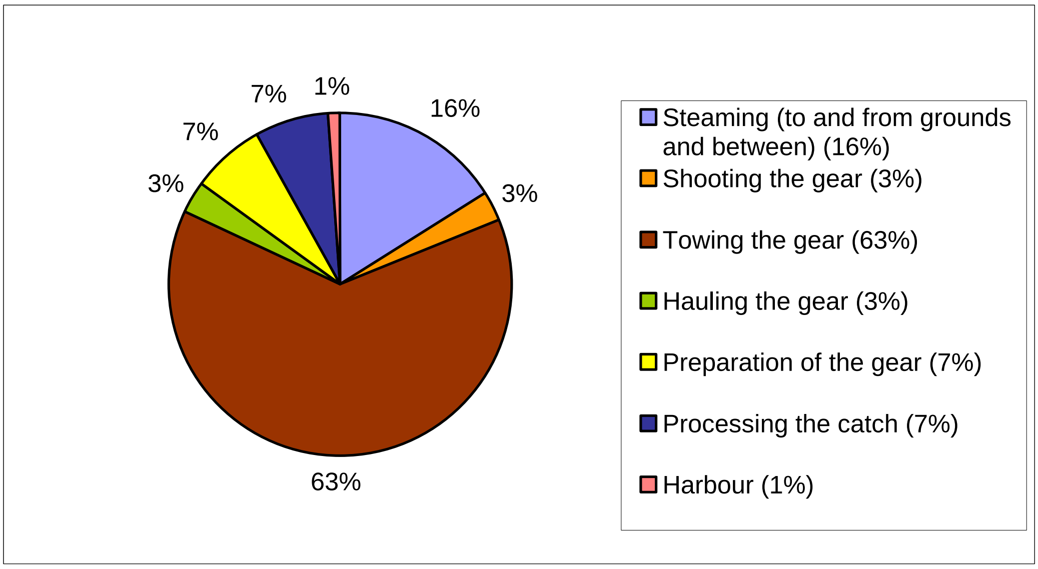


Figure 12. Relative energy use for different operation in processing trawler during fishing with bottom trawl. (Ragnarsson E., 2002.)

Figure 13 shows the contribution of the processing trawler to different impact categories. The environmental effects are predominantly caused by activities during fishing and processing while steaming gives lower impact.

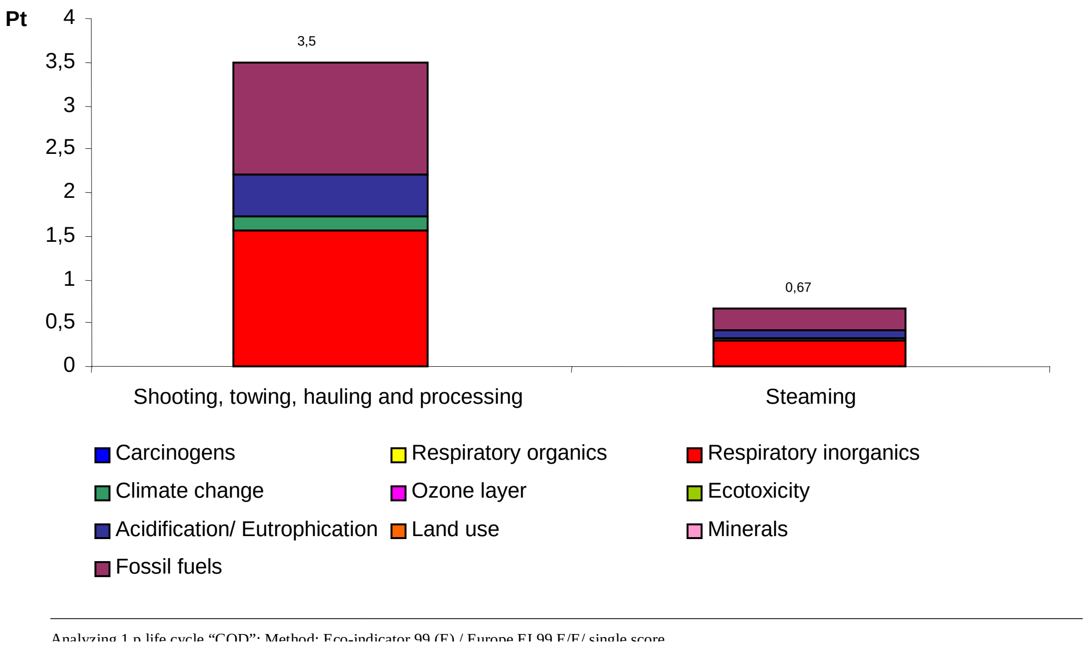


Figure 13. Weighed contribution of the processing trawler to environmental impact categories.

In figure 13 it is evident that the impact category respiratory inorganics have considerable environmental effects, but this category may be overestimated in this particular part of the life cycle. As the emission occurs at sea it may not be as important as it would be in a land based environment. Out in the open sea there are few people around and dilution is high.

The average fuel consumption for processing trawlers using bottom trawls was calculated to be 0.65 (± 0,11) litres fuel/ kg fish (ungutted mixed fish caught by bottom trawl). The processing trawlers use marine gas oil with energy content of 9124 kcal /L fuel. The energy consumption was calculated to be 25 MJ/kg fish (ungutted mixed catch) during the year 2000. The following table shows calculations for the processing trawler regarding oil use and some air pollutant emissions.

Table 4. Information about fuel / diesel oil used and emissions from the processing trawler with bottom trawl.

	CO_2	SO_2	NOx	CO
t/t of fuel	3,17	0,003	0,0078	0,008
g/kg mixed ungutted catch	1759	1,7	43,2	4,4

Guts, which are returned to sea can be regarded as a pollutant in form of nutrient emission to sea, causing eutrophication. In figure 13 this emission is included in the first column and it did not show notable impact in this study.

To increase the resistance of vessels towards organisms such as barnacles, ship hulls are usually cleaned and painted every other year. The amount of anti-fouling paint was calculated to be 0,03 ml wet weight per kg fish (ungutted mixed catch) for the processing trawler and 0,09 ml wet weight paint per kg fish (ungutted mixed catch) for the cargo ship.

6.1.3 Impact assessment excluding processing trawler

When looking at the life cycle in detail and excluding the processing trawler, it is transport that has the greatest impact, see figure 14. As in the case of the fishing vessel, the transport effects are primarily a result of fossil fuels.

The environmental impacts from storage are, on the other hand, relatively small.

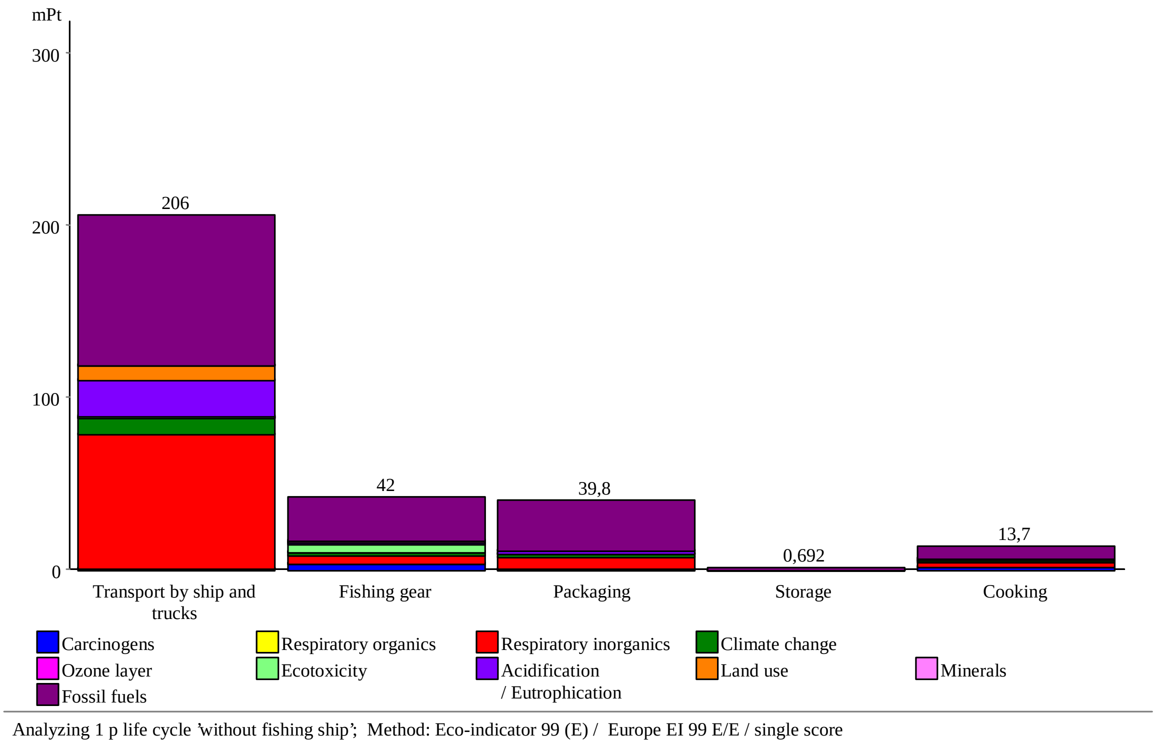


Figure 14. The weighted impact for the life cycle excluding the fishing trawler

6.1.4 Transport

In figure 15 the impacts from different types of transport are given.

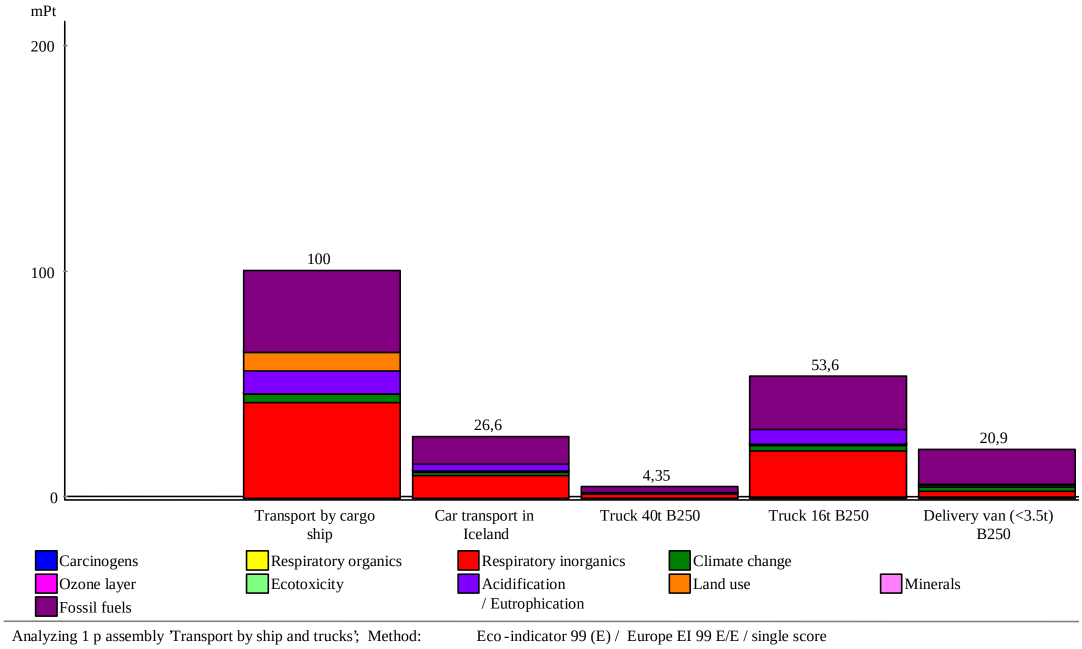


Figure 15. The weighed contribution from the transport phase to the environmental impact categories

The predominating part is transport by cargo ship, followed by car transport in Iceland and truck transport in England. Figure 15 is based on a calculation of tons of goods transported for a certain amount of kilometres by a certain type of vehicle. The figures must be evaluated in context with the number of km behind each of them, see table 5.

Table 5. Distance travelled with goods and type of transport.

Distance	**km**	**Type of transport**
Reykjavik-Grimsby	2000	cargo ship
Domestic in Iceland	405	40t truck
Domestic in England (storage)	50	40t truck
Domestic in England (to wholesaler)	300	18t truck
Domestic in England (to users)	80	Delivery van

When looking at the results for transport of the products from Iceland to the U.K. it is conspicuous that the environmental impact is not proportional to the distance. The main reason is that transporting large quantities of cargo has advantages over transporting smaller quantities. Therefore the van has relatively great impact compared to the short distance it travels.

Table 6 shows the figures calculated for selected air pollutant emissions for the transport phase. These figures can be compared to the emissions from processing trawler given in table 4.

Table 6. Emission for the transport phase of the production system for frozen cod.

	CO_2	SO_2	NOx	CO
g/kg transported product	244	1,7	3,8	1,7

6.2 Biodiversity

The ways chosen to approach biodiversity in this study were to look at by-catch and discards, as well as effects on seafloor.

6.2.1 Seafloor

The area swept per one kg of mixed catch is estimated to be 1000 m^2/kg (estimated for fishing vessel larger than 2000 kW using bottom-trawling gear during the years 1991-1997). The mean depth of the swept area for this size of vessels and type of fishing gear is 468 m and the swept area is 0.94 nm^2 (nautical miles) per haul (Ragnarsson and Steingrímsson , unpublished report).

6.2.2 Discard

There is a growing interest in estimating the amount of discarded fish. Various studies have been made in Europe in order to estimate the amount of discarded fish, but direct figures are not easy to obtain as this problem is somewhat hidden. Most studies are focusing on the effects of discard on stock assessment rather than environmental assessment. A research in 2001 measuring discarded cod and haddock in Icelandic waters (Pálsson et al., 2001) indicated that 1,8% of the cod landed (caught with mixed fishing gear) was discarded and furthermore, if distinguished between different types of fishing gear the number decreased to 0,5% for bottom trawl. A further evaluation of the amount of discard was not available for this study.

Following are some facts on how the management system is used to encourage reduction of discard:

1. On every fishing day there are yield examples taken from the production and they are marked with an orange dot. The Directorate of Fisheries can without warning compare the yield samples to the packaging from the production. If there is a discrepancy the ship can be ordered to minimize the yield factor for the next fishing trip.
2. The Directorate of Fisheries can also, without prior notice, send inspectors on board fishing vessels and the fishery companies have to pay the cost.
3. The percentage of non-target species in the statistic over the total allowable catch has increased during the last 10 years. One of the reasons is that for some years now the Icelandic Ministry of Fisheries has encouraged fishermen to bring by-catch ashore by funding marketing project with the goal of making the non-target species valuable products.

7. DISCUSSION

A LCA study does give information on where the greatest environmental impacts are in a production chain. LCA is though a young method and has limitations as to how to include aspects such as the use of the seafloor, the mortality of target and non-target species. These limitations do cause some underestimation of the environmental impacts of fishing.

The production trail

When following the trail of production of a cod from a processing trawler (filleting onboard), through transport, storage and cooking it is obvious that the energy use of the fishery is the predominating factor, causing the greatest impact on the environment and should be given proper attention in relation to that. The same result is found in a LCA study of Swedish cod, based on data from landed gutted cod in the period of 1997-1999 (Ziegler et al., 2003) This indicating that the predominating factor is the energy consumption regardless of the size of the trawler.

After unloading the fillets from the fishing ship, it is the transport of the fillets that has the most environmental impact. During transport it is noticeable that the environmental impact is not proportional to the distance travelled in different vehicles, but dependent on the type of vehicle. The more efficient the means of transport is the less environmental impact it has for each kilogram transported. In the study, transport by freighter has less environmental impact for a kilogram transported per km than the trailer does.

Environmental impacts of packaging and fishing gear derive mainly from the production and disposal. Cooking is modelled for the UK and the electricity use is giving a noticeable impact. The environmental impact from storage in comparison is relatively small. This is due to the fact that the energy used for storing in Iceland is primarily electricity produced by hydropower and the environmental impacts of hydro power electricity is much less than for the energy produced from fossil fuels. Utilization of the fish is also an important factor and one should take notice to use it well and minimise product loss through the whole trail, that is both by-catch, during processing, transport and at the consumer´s dish as all phases in the production trail do cause environmental effects.

Fishery

When it was revealed that the oil consumption during fishery and the resulting environmental effects was the predominating factor, an increased emphasis was focused on that factor. The use of oil in fishery was analysed and divided between the different operations performed at sea. It turned out that the major part of the oil consumption is used to operate the fishing gear and accounts for over 70% of the total oil consumption during the fishing trip.

Based on these results it can be observed how the environmental cost of one unit of cod fillets could be decreased. As the trawling process is having the greatest impact it would be logical to start by trying to optimise the process of trawling. Many factors affect the fuel consumption per one unit cod fillets during trawling, e.g. the size, type and the material/resistance of the trawl, the density of cod (i.e. the size of cod stock), how the ship and the fishing gear is operated, the shape of the ship, the size and efficiency of the engine and the propeller, condition of the hull, fishing area and weather. An important step in saving energy is to optimise the fuel consumption for various operations, e.g. by using eco-design in the designing phase (Norrblom et al.,

2000) and develop an energy saving improvement simulator (www.rf.is/verkefni/ORKUSPAR/index.htm) and (Yngvadóttir and Arason, 2001). Furthermore, the importance of educating the crew with regards to how the fuel consumption is related to different operations during the fishing trip can never be stressed enough. Saving energy is an attractive option for the fishery, because apart from being environmentally positive it is also cost effective. In this example the environmental improvements go hand in hand with economical gain.

Above there are some suggestions for saving oil, but attempts are also being made to use alternative energy sources. In Iceland the emphasis has been on exploiting the possibilities to use hydrogen as fuel (Árnason et al., 2001). Other researcher are working on the development of an environmental friendly diesel, that is biodiesel made out of excess fish fats or animal fats (Jónsdóttir and Ólafsson, 2002).

Furthermore, it is important to realise that the size of the fishing stocks, i.e. density of catch, has important effects on the use of oil per unit catch and cod fillets. As the fish stock is in better condition, the catch per unit of fishing effort is greater and thus less effort is needed to catch a kilo of fish.

Fuel consumption and emissions

In the Nordic countries there are several studies that have focused on oil consumption of fishing ships from different points of view. In Iceland the focus was on different types and sizes of fishing ships (Rúnarsson, 2000), in Norway the focus was on the oil consumption due to the variation of density of cod over a period of time (Huse et al., in press) and in Sweden on the utilization of energy used (Ziegler and Hansson, 2003). Although all these studies concern the oil consumption in fishery they are not comparable. It is however interesting to look at some similarities.

In this study the oil consumption was calculated to be on average 0.65 ± 0,11 (0,54-0,76) l oil/kg fish (ungutted mixed catch) in year 2000 for processing trawlers (25 vessels, size 80-2000 GRT) using bottom trawl and that is similar to the result made by Rúnarsson where he found this figure to be 0.7 l/kg fish for all kinds of processing trawlers in Iceland for the year 1997. As many of the Icelandic processing trawlers have started using new types of trawls, which have less resistance in sea, the efficiency might increase in near future.

In a Norwegian study (Huse et al., in press), data on oil consumption for the processing trawlers from e.g. 1996 (22 vessels, bottom trawl, size >250 GRT) and 1999 (21 vessels, bottom trawl, size >250 GRT) were calculated to be on average 0,63 l oil/ kg fish (ungutted) in 1996 respective 1,06 l oil /kg fish (ungutted) in 1999. This study shows that the oil consumption calculated for 1 kg fish depends on the density of cod which is varying from one year to another and that there is inverse correlation between the oil consumption per kg fish landed and catch rate. That is when the catch rate is high, less energy is needed per unit.

In the Swedish study the oil consumption for cod fishery, based on data from six trawlers in Sweden in 1997-1999 varied between 0,7 l and 1,22 l oil/ kg gutted cod landed based on the engine load (Ziegler and Hansson, 2003).

The emission of CO_2, and $NO_{x,}$ resulting from burning of oil, differs between the Icelandic and Swedish studies (Ziegler and Hansson, 2003) by the same magnitude as the fuel consumption as would be expected. That is, the emission of CO2 was 1759 g/kg fish (mixed ungutted catch) in Iceland but 3782 g/kg fish in Sweden. The NO_x is 43,2 g/kg fish (mixed ungutted catch) in Iceland but 87,4 g/kg fish in Sweden. The sulphur and CO content of the emissions do, however, not differ in relation to the quantity of the fuel used, indicating that there may be a difference in the quality of the fuel used. For example, regulation no. 784/2001 requires the sulphur content in the marine gas oil used in Icelandic fishing ships to be lower than 0,2%. The SO_2 is calculated to be 1,66 g/kg fish (mixed ungutted catch) in Iceland, while SO_x is reported to be 0,83 g/kg fish in the Swedish cod fishery. Furthermore, the CO is calculated to be 4,56 g/kg fish in Sweden but 4,43 g/kg fish (ungutted mixed catch) in Iceland, which is considerably higher in Iceland if we bear in mind that the trawl fisheries in Iceland use considerably less fuel than the trawl fisheries in Sweden.

Land use / seafloor

The land use in this study is primarily the seafloor swept by the trawl. It could not be included in the numerical LCA study, as the LCA methods have not yet been adjusted to use of sea or “underwater land”. As environmental impacts of land use may be a factor of importance in an environmental study it would be of interest and importance to establish a panel of experts to make it useable. The sea bottom area swept per mixed catch was calculated to be around 1000 m^2/kg fish (mixed catch) in Iceland. This result is based on figures for fishing ships larger than 2000 kW using bottom trawl. Similar results are available from Sweden. Even though comparison has to be performed with great care, as there are different vessels and types of trawls behind the results, it is interesting to observe that in a Swedish study (Ziegler et al., 2003) the impacted seafloor is on average 1711 m^2/kg fish caught by trawls, where approximately 93% of the catch was cod.

The considerable difference in size of area seafloor swept between the Icelandic and the Swedish study are of interest. This could be due to several reasons where the different density of cod is likely to be of considerable importance and hence the state of the cod stock in exactly the same way as oil use is connected to the density of cod.

The seafloor sweeping in Iceland occurs at the mean depth of 468 m and the potential damage is considerably more serious in such deep waters as the deep-sea fauna is characterised by fragile forms (Fosså et al., 2000) while more shallow waters, acclimatised to storm movements and sediment transport, are less fragile. As data on direct mortality of fauna, damage of habitats and alterations of the composition of benthic communities and resulting alterations of ecosystems and food chain is not available at this point, this study did not include these environmental impacts in the numerical results of the LCA. This does cause an underestimation of the environmental impacts of the functional unit.

The scale of the underestimation is questionable and related to type of bottom, for instance would corals be more prone to damage than muddy bottom. But as one kg of filleted fish on the consumers dish needs sweeping of at least approximately 2300 m^2 seafloor it is probably causing a considerable effect

The effects on the ecosystem could not be included in the numerical LCA study, as the LCA methods have not yet been adjusted to such work in sea.

Anti-fouling paint

There has been some concern about chemical use in the fishing industry, with emphasis on anti-fouling paints. TBT and copper are the most used antifouling agents for trawlers and cargo ships. Since antifouling agents such as TBT and copper have been shown to have an important environmental impact in previous studies in fisheries of mackerel (Madsen, 2000) and blue mussel (Andersen et al., 2000), this issue was given special consideration. This was, however, not the case in the study at hand. This may be due to no use of TBT in Icelandic Fisheries.

Biodiversity and discard

It was not possible to take into account the effects of discard when evaluating the environmental impacts of fisheries in this study due to lack of information on the issue. Many marine research institutes are currently researching the effects of by-catch and seafloor sweeping on ecosystems, and it will be interesting to see the results of those researches when they become available. However, it will depend on the similarities of the ecosystems and fishery management systems in question whether these results can be applied to conditions in Iceland or if such studies will have to be performed in Icelandic waters. One idea is to have some sort of monitoring programmes that could provide adequate data of fisheries from large areas, carried out over many years in order to obtain information on by-catch by type of gear, season and years (ICES, 2001). This would provide more data on the dynamics between the marine ecosystem and the effects of fishing on target and non-target species. It is also important to have better knowledge about the dynamic of benthic ecosystems in general and the distribution of fishing efforts in habitats in order to make it possible to include the seafloor effects in a LCA-study (Mattsson and Ziegler, in preperation).

Eco-labelling and Environmental Management Systems

Eco-labelled products seek to assure the customer that they are buying products that have as little impact on the environment as possible. Detailed criteria, based on material and energy use, have been established for many products, taking into account e.g. sustainable use of raw materials. When the methodology of eco-labelling is used for fish products the main focus is on stock assessment and whether fisheries are moving towards sustainability as fish is of wild origin and can not be regulated like earth materials. The criteria for eco-labelling should however not only focus on the importance of sustainability of the fish stocks but should also take into account the measurable environmental impacts of other operations in the life cycle of the product. There the energy use in fisheries is by far the most important factor, followed by transport, packaging, production and disposal of fishing gear.

Environmental management systems (EMS) are also a good and ever increasing way to communicate with customers. The same background information is needed to implement EMS as are for Eco-labelling. The results of a LCA study are a good way to guide companies when implementing EMS on which environmental factors and environmental effects to focus on.

Suggestions for further work

In this study it was observed that there is a lack of an indicator for land use at sea in LCA studies. An interesting indicator to use in this case could be the swept area per kg catch in correlation with depth of the area. It must be taken into account, whether the bottom is rocky, with corals or muddy, and whether it is an virgin area or area that has been swept often before. An estimate of the magnitude of the environmental impacts of land use and ecosystem interactions would preferably have to be performed on international grounds, where the points mentioned earlier in chapter 2.3 could be considered.

It is necessary to take into account the environment the fisheries are carried out in, the nature and origin of the data being used and to consider whether the data is comparable. It would be of great use to establish a group of scientists, including LCA specialists, ecologists and ichthyologists who would focus on the data, the use of data and how to make the data comparable. Classifying the sea bottom could for instance perform this and the condition of fish stocks into groups and evaluate the environmental effects of fisheries with respect to that.

Furthermore, it would be interesting to look at the environmental effects of different ways of producing cod for consumers market, e.g. farmed cod and wild cod. In the same way it would be interesting to evaluate the environmental effects from different ways of fishing e.g. small boats.

It would be interesting to make a LCA of a BAT (Best Available Technology) scenario, where an imaginary fishing vessel would be equipped with the best existing engine or even non-existing hydrogen engine, and catalytic converter, using a low or non toxic paint etc. and see how it would alter the environmental impacts of fishing.

Last but certainly not least, there has been some discussion about the usability of the LCA-software available today or the so-called screening LCA. The concept of LCA is to have a simple tool available for the industry so it can evaluate the environmental impacts of products and constantly make the production more environmentally friendly. This is not the case today, as LCA software are complicated and not user friendly (Nordic seminar on LCA on fish in Denmark 18-19 November 2002). But this technology is in its early stages and currently there are two projects running, in Denmark (LCA i basislevnedsmidler) and Sweden (LCA livsmedel) that aim at making LCA more user friendly. LCA is a good decision making tool for the industry in order to make their product and processes more environmentally friendly and will be even more so in future.

8. CONCLUSION

When analysing the whole LCA, from fishery right to the consumers' dish, it emerged that the greatest environmental impact could be traced to oil consumption during fishery. To catch 1 kg of fish, 0.65 l on average of oil was needed in the year 2000 which gives approximately 400g of fish fillets when is served on a consumers' dish.

As LCA methodology is not advanced enough to handle factors such as the use of seafloor, the effects on stock and ecosystems, the relevance of oil might be overestimated. These limitations do cause some underestimation of the environmental impacts of fisheries. A way to advance the method with regards to those factors would be to establish a group of scientists, including LCA specialists, ecologists and ichthyologists. Such a group could make use of available data to make them comparable.

LCA is a useful decision making tool for the industry to observe the greatest environmental impacts in a production chain. The method needs to be simplified and work is being done to do so as well as making it more user friendly. LCA has also been proved to be useful when defining the criteria for eco-labelling.

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APPENDIX 1

DECLARATION OF ENVIRONMENTAL POLICY BY THE ICELANDIC MINISTRY OF FISHERIES apríl 1998

Premises
The Ministry of Fisheries aims at achieving sustainable utilisation of marine resources and basing management decisions on the best available scientific grounds. Every effort shall be made to ensure that the biodiversity and ecosystem of the ocean will not be threatened. Government decisions should show regard for the obligation of each generation to pass on to its descendants a viable environment, for the duty of nations to protect the ocean biosphere and ecosystem, and for the importance of providing healthy products for consumers of the Icelandic marine harvest.

1. Conservation and sustainable utilisation of the live marine resources in Icelandic waters

The objective set by the Ministry is to ensure that treatment of commercial marine stocks in Icelandic waters will provide maximum long-term productivity.

Harvesting strategy

Decisions on harvesting must be based on scientific grounds and on utilising the catch so as to minimise waste and maximise production value.

Fishing of commercial stocks

Fisheries management shall provide implicit encouragement to treat living marine resources properly and ensure optimal utilisation of all factors of production. Decisions shall be based on clear premises and the preparatory process is to include extensive consultation. Decisions shall be actively enforced through effective surveillance and control.

Catch rule

Rules shall be developed providing for the utilisation of individual commercial stocks. In formulating such catch rules, the precautionary approach shall be followed with the aim of achieving maximum long-term productivity.

Fishing gear and handling of catch

Support shall be given for the development of selective fishing gear which have favourable effects on the environment, the resource and the catch, and their use encouraged. The Ministry shall set rules aimed at ensuring that catch is not allowed to spoil. No fish that can be utilised may be discarded and fisheries shall be managed with the aim of reducing danger of discards.

Protection of areas

Fishing is prohibited in specific areas or with specific types of fishing gear in order to protect spawning fish and juveniles. Ocean areas are kept under surveillance in order to enable prompt response.

Processing of marine products

Rules on processing of catch shall always be aimed at preserving the healthiness of the catch and products until they reach the consumer. Efforts shall be made to ensure that production technologies employed provide optimal environ-mental protection and processing. The goal shall be to utilise every part of the catch.

Research policy

The policy of the Ministry is to have effective marine research and research in fish processing carried out in Iceland to ensure the application of the best scientific evidence in each instance. To this end, co-operation with domestic and foreign scientific institutions and other parties is sought.

Marine research

Research is to be carried out on the marine ecosystem, commercial marine stocks, oceanography and fishing gear, and emphasis placed on multi-stock research. Active participation in international co-operation, for instance within the International Council for the Exploration of the Sea, is important to obtain a critical assessment of the methods used in Iceland and to apply the results of the most recent research.

Research in fish processing

Research on the handling and processing of marine catch is aimed at providing Icelandic processors with continual access to reliable information on how to improve the utilisation of marine catch and other inputs.

Connections with other scientific disciplines

The Ministry places emphasis on research in various disciplines which can prove useful in resource management, such as economics, marketing, law, political science, sociology and geology.

2. Fishing in international waters

The policy of the Ministry of Fisheries is aimed at sustainable utilisation of live resources in international waters. Decisions on fisheries management are to be based on the best scientific evidence available. Fisheries shall be managed in accordance with appropriate international rules, by the competent institutions or organisations. Only nations following the rules should be granted permission to fish in these areas.

Harvesting strategy

Emphasis is placed on basing utilisation of stocks in international waters on catch rules, on having effective surveillance systems and a management system which can respond promptly to indications of ecological changes.

Research policy

The Ministry of Fisheries wishes to increase research in international fishing areas and use its influence to see to it that the parties carrying out research are duly rewarded.

3. Pollution and effluents

The Ministry of Fisheries will promote increased research concerning ocean pollution, both through environmental monitoring and investigating the impact of pollution on the ecosystem, as well as on marine products. The Ministry of Fisheries emphasises the necessity of concluding the international agreements and taking measures necessary to prevent all discharges of persistent and radioactive substances into the oceans from threatening the biosphere.

Energy consumption

Icelandic fishing enterprises are encouraged to minimise energy consumption and utilise renewable sources of energy wherever possible. Emissions of greenhouse gases shall be reduced as much as possible, taking into con-sider-ation the dependence of the nation on fishing.

4. Trade

In the international arena, the Ministry of Fisheries desires that Iceland promote free trade in fish and fish products, together with the elimination of government subsidies which encourage over-utilisation of live marine resources and damage to their environment. The Ministry of Fisheries opposes measures to restrict market access aimed at influencing utilisation of marine resources.

APPENDIX 2. LCA FOR COD - INVENTORY ANALYSIS

Fishing trawler	Material input	Amount per functional unit	Comments, boundary conditions and assumptions	Amount /kg ungutted mixed catch	References, source of information	pt
Steaming	Diesel engine ship C	30,8 MJ	16% of total fuel consumption	1,42 MJ	Information from landing declarations, oil companies, fisheries, oil consumption report. Buwall files in SimaPro on oil production and emissions. The average fuel consumption for processing trawlers using bottom trawls was calculated 0.65 (± 0,11) liters fuel/ kg mixed fish caught by bottom trawl. The fuel used is diesel oil with energy content of 9124 kcal/L fuel. The yield to produce cod fillets is assumed to be 41,5 %	1,4
Shooting, towing, hauling, processing	Diesel engine ship C	453,3 MJ	84% of total fuel consumption(shooting the gear 3%,towing the gear 63%,hauling the gear 3%, gear preparation 7%, processing the catch 7%, harbour 1%)	20,9 MJ		7,48
	R22 (coolant) ETH T	0,0042 kg	Approximately 150 kg per year for a processing trawler	0,19g	Information from processing companies	9,44E-05
	Copper in anti-fouling paint	0,00375 kg	220l of paint/1000m^2 every other year, 2 layers of 40% copper(I)oxide paint, end of life is modelled as emission to water.	0,17 g	Information on paint and amount needed from fisheries, paint manufacturer. Data on copper is taken from Delft University file in SimaPRo.	0,00049
			The calculated amount of wet weight anti-fouling paint used is	0,03 ml		

Fishing gear	Material input	Amount per functional unit	Comments, boundary conditions and assumptions	Amount /kg ungutted mixed catch	References, source of information	pt
	PP granulate	0,052 kg	The bottom trawl consist of a net and rope of polypropylene (PP), 3-5 ton, with lifetime 6-8 months. Two steel otter boards 3,4 - 4,4 ton each with lifetime around 18-36 months. Steel towing wires weighing around 20 tons total with lifetime around 10-18 months. After they have been used they are partly reused as a bridles. Steel chains are 3-5 tons with lifetime of 8-12 months.	2,4 g	Information from fisheries and municipal waste company on end of life modelling. Data from BUWAll SimaPro file.	0,01316
	Steel alloy	0,22 kg		10,1 g		0,03366
Transport	**Material input**	**Amount per functional unit**	**Comments, boundary conditions and assumptions**	**Amount /kg ungutted mixed catch**	**References, source of information**	**pt**
	Car transport in Iceland	3,64 tkm	Domestic transport in Iceland, 405 km. 22 tons in container.		Information on use of oil from transporters and on type of oil from BUWALL SimaPro file.	0,0266
	Transport by cargo ship	17,4 tkm	Transport from Reykjavik to Grimsby, 1043 sm. 25 tons/container, 120 container/ship, 70% load on ship.		Information on use of oil from transporters and on type of oil (emissions) from Bunkerworld.com, Icelandic EPA and SimaPro file from Delft University.	0,1

	Truck UK 40t	0,54 tkm	Average transport from harbour to Central Depo		Information on driving distances estimated by interviews with salesman.	0,00435
	Truck UK 16t	2,7 tkm	Average transport from Central Depo to wholesaler		Buwall files on transport used in SimaPro	0,0536
	Delivery van	0,72 tkm	Average transport from wholesaler to user			0,0209
	Copper in anti-fouling paint	0,00026 kg	220l of paint/1000m2 every other year, 2 covers of 40% copper(I)oxide paint, end of life is modelled as emission to water.		Information on paint and amount from fisheries and paint manufacturer. Data on copper is taken from Delft University file in SimaPRo	0,00034
			The calculated amount of wet weight anti-fouling paint used is	0,09 ml		
Storage	**Material input**	**Amount per functional unit**	**Comments, boundary conditions and assumptions**	**Amount /kg ungutted mixed catch**	**References, source of information**	**pt**
	R134 coolant	0,0000378 kg	5 kg per container with lifetime of 3 years. Time for fish in container 21 days		Average time in transport and storage is estimated, information from producers, transporters and sales companies.	5,18E-06
	Electricity from hydropower	0,302 kWh	Storage in Iceland, 2,5 kWh per container, 14 days in storage, 22 tons per container			0
	Electricity GB	0,0175 kWh	Storage house in Great Britain, 5 days, 60% efficiency of storage			0,00069

Cooking	Material input	Amount per functional unit	Comments, boundary conditions and assumptions	Amount /kg ungutted mixed catch	References, source of information	pt
	Electricity GB	0,35 kWh	Deep frying, electricity use 0,7kWh, cooking time 30 min.		Buwall file on electricity in GB	0,0137
Packaging	**Material input**	**Amount per functional unit**	**Comments, boundary conditions and assumptions**	**Amount /kg ungutted mixed catch**	**References, source of information**	**pt**
	Kraft liner brown	0,0805 kg	The packaging consists of a box Kraft liner and 10 plastic sheets as interlayer. The primary packaging is put three and three together in secondary packaging, a corrugated cardboard box, and wrapped with plastic strings.		Packaging manufacturer on material input. Disposal in GB 90% landfill and 10% incineraration from Environmental Protection Statistic, www.defra.gov.uk) Buwall files in SimaPRo.	0,00127
	Kraft liner white	0,0735 kg				0,00197
	LPDE	0,103 kg				0,0292
	Corr. Cardboard	0,12 kg				0,00506
	PE Granulate	0,0033 kg				0,0009