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Life Cycle Assessment on fresh Icelandic cod loins

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Report summary

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Authors / Höfundar	Birgir Örn Smárason, Jónas R. Viðarsson, Gunnar Þórðarson and Lilja Magnúsdóttir		
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Summary in English:	With growing human population and increased fish consumption, the world's fisheries are not only facing the challenge of harvesting fish stocks in a sustainable manner, but also to limit the environmental impacts along the entire value chain. The fishing industry, like all other industries, contributes to global warming and other environmental impacts with consequent marine ecosystem deterioration. Environmentally responsible producers, distributors, retailers and consumers recognize this and are actively engaged in mapping the environmental impacts of their products and constantly looking for ways to limit the effects. In this project a group of Icelandic researchers and suppliers of fresh Icelandic cod loins carried out Life Cycle Assessment (LCA) within selected value chains. The results were compared with similar research on competing products and potentials for improvements identified. The project included LCA of fresh cod loins sold in the UK and Switzerland from three bottom trawlers and four long-liners. The results show that fishing gear has considerable impact on carbon footprint values with numbers ranging from 0.3 to 1.1 kg CO_2eq/kg product. The catching phase impacts is however dominated by the transport phase, where transport by air contributes to over 60% of the total CO_2 emissions within the chain. Interestingly, transport by sea to the UK emits even less CO_2 than the domestic transport. Minimizing the carbon footprint, and environmental impacts in general, associated with the provision of seafood can make a potentially important contribution to climate change control. Favouring low impact fishing gear and transportation can lead to reduction in CO_2 emissions, but that is not always practical or even applicable due to the limited availability of sea freight alternatives, time constrains, quality issues and other factors. When comparing the results with other similar results for competing products it is evident that fresh Icelandic cod loins have moderate CO_2 emissions.		
English keywords:	*Carbon footprint, life cycle assessment, fisheries, Icelandic cod loins*		

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Ágrip á íslensku:	Samfara mikilli fólksfjölgun og aukinni fiskneyslu stendur sjávarútvegur á heimsvísu nú frami fyrir því mikilvæga verkefni að nýta fiskstofna á sjálfbæran hátt á sama tíma og þau þurfa að lágmarka öll umhverfisáhrif sem hljótast af veiðum, vinnslu, flutningunum og öðrum hlekkjum í virðiskeðjunni. Sjávarútvegur, líkt og allur annar iðnaður, stuðlar að hlýnun jarðar og hefur jafnframt í för með sér ýmiss önnur umhverfisáhrif sem hafa skaðleg áhrif á lífríki sjávar. Fyrirtæki sem vilja sýna félagslega- og umhverfislega ábyrgð í sínum rekstri gera sér fulla grein fyrir þessu og sækjast því eftir að fylgjast betur með umhverfisáhrifum sinnar framleiðslu og leita leiða til að draga úr þeim. Með þetta í huga tók hópur íslenskra rannsóknaraðila, sjávarútvegsfyrirtækja og sölu- og dreifingaraðila saman höndum, til að framkvæma vistferilsgreiningu (LCA) í völdum virðiskeðjum ferskra þorskhnakka. Niðurstöðurnar voru svo bornar saman við niðurstöður sambærilegra rannsókna sem gerðar hafa verið á samkeppnisvörum, jafnframt því sem leiðir til að draga úr umhverfisáhrifum innan áðurnefndra virðiskeðja voru kannaðar. Rannsóknin náði til ferskra íslenskra þorskhnakka sem seldir eru í Bretlandi og Sviss. Hnakkarnir voru unnir úr afla þriggja togara og fjögurra línubáta. Niðurstöðurnar sýna að tegund veiðarfæris hefur mikil áhrif á sótspor / kolefnisspor afurðanna þar sem línubátarnir komu heilt yfir töluvert betur út en togararnir. Sótspor einstakra skipa í rannsókninni var á bilinu 0.3 til 1.1 kg CO2eq/kg afurð, sem verður að teljast nokkuð lágt í samanburði við fyrri rannsóknir. Þegar kemur að því að skoða alla virðiskeðjuna er það hins vegar flutningshlutinn eða flutningsmátinn sem skiptir langsamlega mestu máli þ.s. sá hluti ber ábyrgð á yfir 60% sótsporsins þegar varan er flutt út með flugi. Sé hún hins vegar flutt út með skipi verður sótspor flutningshlutans sáralítið og fer þá innanlandsflutningur að skipta meira máli en flutningurinn yfir hafið. Lágmörkun umhverfisáhrifa sem hljótast af veiðum, vinnslu og dreifingu sjávarafurða getur haft mikilvægt innlegg í baráttunni gegn hlýnun jarðar. Með því að velja veiðiaðferðir og flutningsmáta með tilliti til sótspors er unnt að draga umtalsvert úr kolefnisútblæstri, en það þarf þó einnig að hafa í huga að það er ekki ávalt mögulegt eða raunhæft að velja eingöngu þá kosti sem hafa lægst sótspor. Niðurstöður þessara rannsóknar og samanburður við niðurstöður sambærilegra rannsókna sýnir að ferskir íslenskir þorskhnakkar sem komnir eru á markað í Bretlandi og Sviss hafa hóflegt sótspor og eru fyllilega samkeppnisfærir við aðrar fiskafurðir eða dýraprótein.
Lykilorð á íslensku:	*Sótspor, kolefnisspor, vistferilsgreining, fiskveiðar, íslenskir þorskhnakkar*

Contents

1 Introduction

With growing human population and increased fish consumption, the world's fisheries are not only faced with the challenge to harvest fish stocks in a sustainable manner, but also to limit the environmental impacts contributed to by the fishery itself and other links in the supply chain. The fishing industry, like all other industries, contributes to global warming and other environmental impacts with consequent marine ecosystem deterioration. The aim of this report is to identify the main environmental impact categories within the value chain of fresh Icelandic cod loins, compare the results to similar studies done for other competing products and identify potentials for improvements.

Fresh fillets from Iceland are traditionally sold in the most demanding markets of Europe and America. The products have a certain competitive advantage over many competing products, where Icelandic producers can demonstrate supply security all year round, even and good quality, good traceability and sustainable exploitation of stocks. Thus, Icelandic fresh fish producers have managed to maximize the value of their products over the years.

In recent years however, wholesalers, retailers and consumers have increasingly requested more information on sustainability and environmental impacts of products in many of Iceland's major trading countries. Parallel to that, the demand for eco-labelling has become visible from many important customers, which has led the producers themselves to acquire certification from sources such as IRF (Iceland Responsible Fisheries), MSC (Marine Stewardship Council) and FOS (Friend of the Sea). These Environmental certification schemes however only provide assessment on whether the catch comes from sustainable stocks and whether fishing methods are sustainable. They do not, however, assess the overall environmental impacts of the products, such as energy use, emissions, packaging, recovery etc. These are factors that individual buyers are increasingly starting to ask for from manufacturers and other suppliers. Retailers have even put forward the goal of reducing the Carbon Footprint of their products and show customers CO_2 information of individual products.

It is therefore clear that those who can provide the most accurate information on environmental impacts of their products and therefore demonstrate that they are taking these issues seriously, will gain goodwill among their customers and ensure a competitive advantage over other producers.

Icelandic fresh fish producers are in many cases receiving higher prices than competitors in key markets today. Access to these markets and continuation of the price premiums are though not to be taken for granted. Lessons learned in the pasts have for example showed that markets can be lost if suppliers are not able to meet new requirements set forth by their customers. Requirements for MSC certification has for example led to such incidents, where Icelandic producers were not prepared for new demands coming from important customers. Fishmongers, distributors, people in charge of sourcing for retail chains and regular consumers are now actively seeking information about carbon emissions and other environmental impacts. The goal of this project is to obtain this data. The project will enable suppliers to show customers that minimization of environmental impacts is an issue being focused on. The results of this project will be in the form of Life Cycle Assessment (LCA) where the environmental impacts of one kg of fresh cod loins, ending at wholesalers in the UK and Switzerland, will be analysed. Data from trawlers, long-liners, processing plants and from different transportation methods will be included using the ISO standardized method with a focus on Global Warming Potential (GWP) from the CML impact assessment method.

LCA's use has been increasingly encouraged within the EU framework. It is now also a part of many eco-labels such as the EU-flower and the Nordic swan. It can be added that the US Environmental Protection Agency (EPA) focuses on and encourages the use of LCA for assessing the environmental impacts of products, and by doing that the production process can be analysed in order to decrease impacts. The methodology can also be used to strengthen marketing of products.

LCA's use in Iceland has not been prominent in recent decades, but has been gaining much attention recently. LCA has been used to assess the environmental impacts of fisheries and processing worldwide (e.g.: Ziegler et al. 2003, Ziegler & Hansson 2003; Ellingsen & Aanondsen 2006; Svanes et al. 2011b; Eyjolfsdottir et al. 2003; Guttormsdottir 2009; Vazquez-Rowe et al.

2011; Ziegler & Valentinsson 2008; Vazquez-Rowe et al. 2010; Vazquez-Rowe et al. 2012; Winther et al. 2009; Ziegler et al. 2011) and has at least twice been conducted on Icelandic fisheries and processing (Eyjolfsdottir et al. 2003); (Guttormsdottir 2009).

2 Methodology

One aspect of achieving sustainability is to measure and compare the environmental impacts of production and supply of goods and services in order to minimize impacts. The life of every product starts with the design/product development, and from that point adoption of resources and raw materials, production, use and end of life activities. LCA is a methodology used to estimate and evaluate the overall environmental impacts of a product's life cycle.

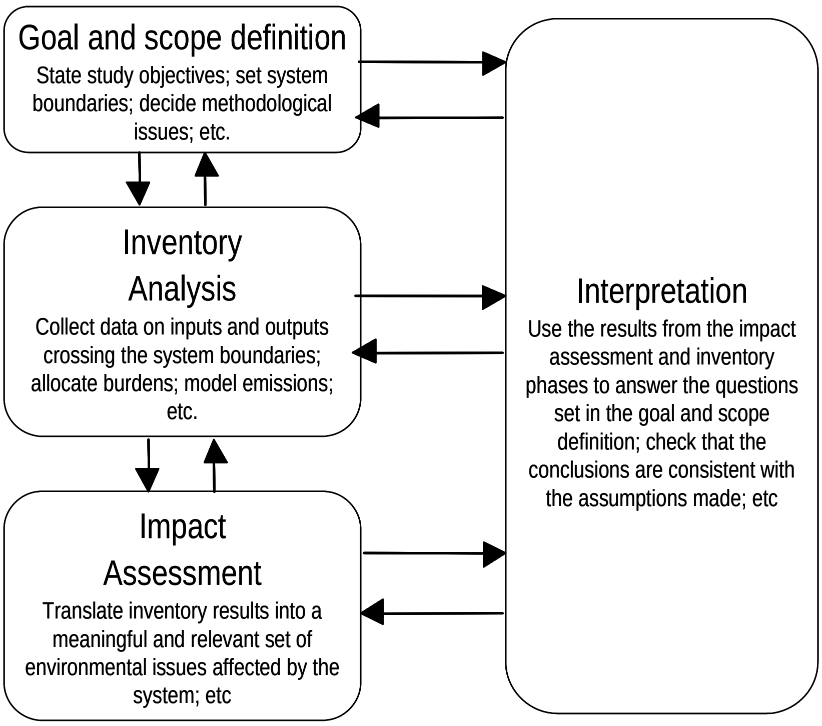

Figure 1. The 4 steps in conducting Life Cycle Assessment as standardized in ISO 14040 and 14044 (ISO 14040:2006(E)).

Life cycle assessment is based on four steps, as standardized by the ISO standard 14040 series (ISO 14040:2006(E)) and presented in figure 1. Those steps are: Goal and scope, inventory analysis, impacts assessment and interpretation. In addition to these steps it is necessary to determine the functional unit. Definition of the functional unit is the foundation of life cycle assessment because the functional unit sets the standard in order to compare two or more products and for improvement analysis. All data collected during the project will be put in context with the functional unit. When comparing different products that fulfil the same function, the definition of the functional unit is very important. One primary purpose of the functional unit is to provide a reference to which input and output data can comply with.

System boundaries define process/activity (e.g. manufacturing, transport and waste), and the input and output materials that shall be included in the analysis. Definition of system boundaries vary between research projects as they define what is included in the assessment. System boundaries can certainly affect the results, it is therefore important to encourage a transparent working process, and report every assumption made.

It should be noted that the scoping of this project (including functional unit, allocation and system boundaries) will be in accordance with the ISO 14040 series standards for LCA and the Norwegian NS 9418:2013 standard on carbon footprint for seafood.

2.1 Goal and scope

The aim of the project is to carry out a Life Cycle Assessment on Icelandic fisheries, particularly in regards to fresh Icelandic cod products that are sold at markets where sustainable sourcing and mitigating environmental impacts are emphasized. The results can be used by suppliers and their customers to favour low impact alternatives, to demonstrate to wholesalers and retailers that measures are being taken to improve environmental impacts and to compare Icelandic fishery practices and cod-loins with competing products and activities.

In this study, Life Cycle Assessment will be conducted on fresh cod loins made from raw material from different fishing fleets (gear type) and transported by different modes of transport to the UK and Switzerland. Catches from small line-boats, large auto-line long-liners, and trawlers will be analysed. The cod products will be transported by air- and sea freight to trading partners. To obtain meaningful results, data from a whole calendar year 2012 will be used. Life Cycle Assessment will be made in the SimaPro software. When the LCA is complete, the results will be compared with similar studies including various seafood and other foodstuffs. Possible improvements will be recommended in order to reduce environmental impacts.

2.2 Functional unit

The functional unit of this LCA will be 1 kg of fresh cod loin caught in Icelandic waters (by small line-boat, large long-liner and trawlers), processed and packaged in Iceland and transported to wholesalers in UK and Switzerland (by air and sea).

2.3 System boundaries

The system boundaries for this study were carefully chosen to be in line with similar studies in this field. This is important to be able to compare the outcome of this study to other studies with similar functional units.

The number of life cycle phases in a study can be subjective but are usually determined by the objectives of any given study. The exclusion or inclusion of phases and processes are determined by the availability of data and the established importance of processes in contributing to impacts (Parker, 2012). The life cycle stages are shown in a simplified way in Figure 2.

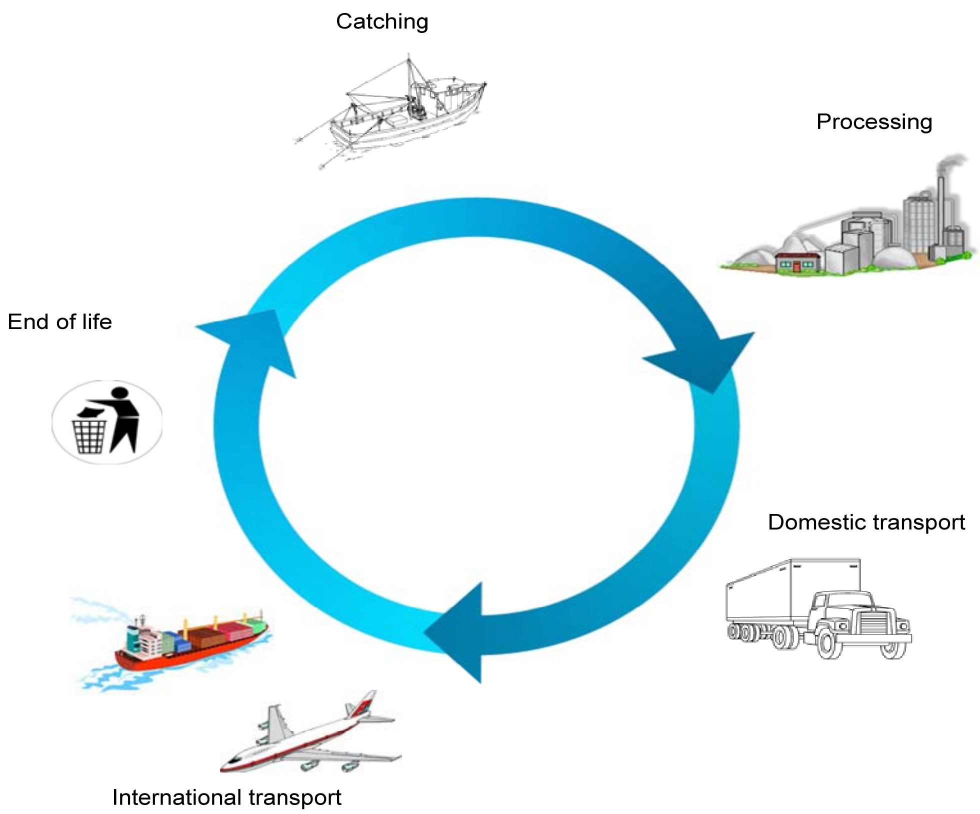

Figure 2: Life Cycle stages of the study

The life cycle of the functional unit is divided into four main phases; catching, processing, domestic transportation and international transportation. System boundaries include background processes such as raw material extraction, energy production, production of packaging material, fishing gear and all chemicals such as cleaners and oils. The production of vessels and the production input for bait was left out, due to the anticipated triviality of their contributions (cut-off criteria).

2.4 Allocation and Assumptions

Allocation in LCA studies is an ongoing problem and issue for debate. Although international methodological standards have addressed this matter, considerable inconsistency is evident. This can be the cause of the major methodological differences between LCA studies.

For the purpose of this study, mass allocation will be used to partition the environmental impacts in all systems yielding co-product ingredients, i.e. allocating co-products based on their mass. Other allocation methods were considered such as system expansion, economic value and gross nutritional energy content. The use of mass allocation is however in line with many seafood studies done in recent times. Parker (2012) found out that 38% of seafood studies used mass allocation and 30% economic allocation out of 100 studies when reviewing recent seafood LCA studies. The use of mass allocation provides stability and encourages the food industry to make use of by-products because high environmental burden is allocated to them. It is also less time consuming compared to other methods. Economic allocation for example, is affected by high variability in both fish and feed input prices in recent years, making this method reasonably unstable over time.

Allocation examples arose on several instances throughout this project, mainly when dealing with different type of fish catch and co- or by-products in the processing phase, since only the cod loin was assessed. This led to assumptions regarding the utilization of cod. Throughout the project, a utilization factor of 0,84 for cod was used, which means about 16% of catch is regarded as viscera. In order to make comparison easier it was assumed that all of the fish (gutted with head on) were utilised and that only the liver (5%) and roes and milts (2,5%) from the viscera were utilised. Total utilization is therefore 91,5% (Sigurgísladóttir et al., 2010).

Utilization however differs between companies and processing plants but for the sake of this project, mean values had to be found and somewhat assumed.

Other assumptions regarding the catching phase were that 20% of the fishing gear replacement were lost in the oceans. This loss was accounted as emissions to water and assessed as chemical components of the fishing gear parts.

2.5 Impact assessment method

The environmental impacts associated with the studied system were calculated using the CML-IA Baseline midpoint approach, originally developed by the Centre for Environmental Studies (CML) of the University of Leiden in the Netherlands (Buonocore et al., 2009). In a midpoint approach, the life cycle inventory results are characterized into relevant environmental impact categories. They are then shown in reference units to indicate their potential contribution to specific environmental impacts. If global warming is taken as an example, all emissions that contribute to that particular impact category are interpreted in CO_2 eq. This value shows the potential contribution to environmental impacts, not the actual extent of resulting damage of the environmental impact (Ayer & Tyedmers, 2008).

2.6 Impact categories

The impact categories chosen for this study reflect the most common and important categories used in fishery studies. The environmental impact categories quantified in this analysis were global warming potential (GWP100a), Acidification, Eutrophication, Human toxicity, Marine aquatic ecotoxicity, Freshwater aquatic ecotoxicity and Ozone layer depletion. By including multiple impact categories, the results provide a broader understanding of the environmental impacts and helps identifying trade-offs between impacts.

The four most commonly used impact categories in seafood LCA are global warming potential, acidification potential, eutrophication potential and cumulative energy demand (Parker, 2012). These impact categories were all chosen for this study as well as human, marine and freshwater toxin potentials in order to address human and ecological health as well as depletion of the ozone layer.

2.7 Life cycle inventory

The life cycle inventory analysis is the fundamental basis of every Life Cycle Assessment (LCA) study. It involves the collection and compilation of all the data required to quantify the relevant input and output data associated with the functional unit. This data is used to create a model that contains all inputs and outputs of the product and their amount.

Collection of data was as accurate and up-to-date as possible. All of the data collected was gathered with interviews, questionnaires and on-site measurements. Official data was always used wherever possible. If information was not available, estimations was used or secondary data from databases included in the SimaPro software package.

In life cycle assessment methodology, a product system implies a collection of unit processes that are materially and energetically connected and perform one or more defined functions. The unit process is the smallest unit of a product system for which data is collected. The system boundaries define which unit processes belong to the LCA study, but the aim is to include all relevant unit processes, from raw material production to the transportation between all stages (Silvenius & Grönroos, 2003). Data availability and data quality are a well know problem in LCA studies. Most studies rely on both background data from databases and real foreground data (site samples).

It should be noted that the scoping of this project (including functional unit, allocation and system boundaries) was in accordance with the ISO 14040 series standards for LCA and the new Norwegian NS 9418:2013 standard on carbon footprint for seafood.

The life cycle of the functional unit was divided into four main phases: catching, processing, domestic transport and transportation to either the U.K or Switzerland by air or sea. Data was gathered for the year 2012.

2.8 Catching

In the inventory of the catching phase, the following information was included:

- Oil consumption (production and emissions of usage)
- Fishing gear replacement production

- Fishing gear loss to the ocean and its corresponding emissions to the marine ecosystems.
- Hydraulic fluid and lubricant (production)
- Antifouling paint (production and emissions to the ocean of the antifouling paint loss).
- Ice (production)
- Cod catches and total catches.

The catching phase was the most data intensive phase, including three bottom trawlers and four long-liners, the two most widely used fishing methods in Iceland.

In the case of bottom trawlers, the following three vessels have been studied:

Figure 3. Páll Pálsson ÍS-102 - Vessel 1274

Páll Pálsson ÍS-102 (vessel 1274), a 53,68 meters long and 9,5 m wide trawler built in 1972.
Engine: Niigata 1988 – 2300 HP.
Catch in 2012: Total: 4.556.592 kg, Cod: 3.477.354 kg.
Owner: Hraðfrystihúsið - Gunnvör hf.

Figure 4. Farsæll SH-30 - Vessel 1629

Farsæll SH-30 (vessel 1629), a 26,16 meters and 7 meters wide trawler built in 1983.
Engine: Caterpillar – 912 HP.
Catch in 2012: Total: 1.430.330 kg, Cod: 472.934 kg.
Owner: FISK – Seafood ehf.

Klakkur SK-5 (vessel 1472), a 51,83 meters long and 10,76 meters wide trawler built in 1977.
Engine: B&W Alpha – 2200 HP.
Catch in 2012: Total: 4.074.166 kg, Cod: 3.575.433 kg.

Owner: FISK – Seafood ehf.

Figure 5. Klakkur SK-5 - Vessel 1472

In the case of long-liners, the following four vessels have been studied:

Figure 6. Brimnes BA-800 - Vessel 1527

Brimnes BA-800 (vessel 1527), a 21,31 meters long and 5,2 meters wide long-liner/Danish seine built in 1979.

Engine: Cummins – 607 HP.
Catch in 2012: Total: 724.253 kg, Cod: 324.682 kg.
Owner: Oddi hf.

Figure 7. Núpur BA-69 - Vessel 1591

Núpur BA-69 (vessel 1591), a 35,51 meters long and 7,6 meters wide long-liner built in 1976.

Engine: Caterpillar – 980 HP.
Catch in 2012: Total: 2.224.160 kg, Cod: 1.290.214 kg.
Owner: Oddi hf.

Figure 8. Gestur Kristinsson ÍS-333 - Vessel 2631

Gestur Kristinsson ÍS-333 (vessel 2631), a 10,96 meters long and 3,91 meters wide long-liner built in 2004.
Engine: Yanmar – 427 HP.
Catch in 2012: Total: 536.000 kg, Cod: 316.666 kg.
Owner: Fiskvinnslan Íslandssaga hf.

Figure 9. Kristján ÍS-816 - Vessel 2614

Kristján ÍS-816 (vessel 2614), a 11,46 meters long and 3,36 meters wide long-liner built in 2004.

Engine: Cummins – 411 HP.
Catch in 2012: Total: 488.000 kg, Cod: 248.232 kg.
Owner: Fiskvinnslan Íslandssaga hf.

Data for the catching phases was gathered from each vessel's database from the year 2012. All of the abovementioned inventory was gathered for all vessels, but rules for different fishing gears applied.

2.9 Processing

For the processing phase the same data was used for all vessels. Data was gathered from Islandssaga's, Oddi's and FISK's processing plants and mean values used. Information such as energy consumption (energy production and emissions of the production), water consumption, all packaging material (production and emissions of the production), cooling agents (production and emissions of the production) and cleaning products (production, emissions of production and emissions of usage) was used. For the cleaning, all soaps, detergents, sterilization liquids, oil dissolvers and hand towels which are used for cleaning during the fish processing were included.

In the inventory of the processing phase, the following information was included:

- Use of electricity, fuel and other energy sources
- Receiving, storage, processing, packaging and other handling of the product
- Transport within the processing
- Operation of ventilation and cooling systems
- Cleaning of processing plant and the usage of detergents
- Waste

Cod loins are packaged into EPS boxes (5 kg boxes most commonly), each containing two cooling mats and two absorbing pads before being sent to distribution.

2.10 Transportation

In the inventory of the distribution and retail phase, the following information was included:

- Fuel for propulsion, loading, unloading and operation of refrigerating system
- Construction, maintenance and disposal of transport
- Production and distribution of fuel
- Emissions and production of refrigerants
- Construction and maintenance of roads, ports, airports and other infrastructure
- Waste and losses

Data for transportation was gathered from the involved partners, respective transportation companies and the EcoInvent database for both domestic and international transportation. Each vessel's catch is transported to Reykjavík by truck for the sea freight and to Keflavík airport for the air freight. The cod loins are shipped to the U.K by air and sea, and by air to Switzerland where they are transported and stored in a retail warehouse. The transportation is calculated as Payload – Distance or kg/km, meaning the functional unit of 1 kg is multiplied with the total distance in km.

2.11 Waste and disposal

Waste streams are output from seafood production systems without any commercial value. If the output has a commercial value, it represents a by-product and is not to be regarded as waste. The following rules apply to different types of waste:

- For waste that is disposed of, any emissions should be included, from transportation and other handling of the waste until disposal and emissions from the landfill
- For waste that is recycled, the transport and handling until final disposal should be included. This also applies if the waste is incinerated, including the heat of combustion
- For waste that is incinerated, emissions from the combustion included.

For waste disposal, the end of life of the packaging material and the fishing gear replacement was accounted for. For all the recycling processes the avoided environmental impacts and energy inputs were calculated in their corresponding phases, meaning there is no specialized waste/disposal phase.

3 Results

The results of the study are presented in this chapter, include findings from the gathering, analysis, calculations and assumptions of data coming from various sources connected to this work. The study was carried out fulfilling the ISO 14040 series standards on LCA and was modelled in the SimaPro software using the EcoInvent 3 database.

The environmental impacts of catching, processing and transporting 1 kg of cod loin have been assessed using the CML-AI Baseline impact assessment method. The results cover data from Icelandic bottom trawlers and long-liners of different sizes, type and age.

3.1 Bottom Trawlers

Three bottom trawlers provided data for the LCA, two of which are rather large vessels that target cod most of the year and have fairly good quotas and one that is much smaller and primarily targets other species than cod.

3.1.1 Vessel 1274 (Páll Pálsson ÍS)

The results from vessel 1274 show that the catching phase contributes to 56% of the total environmental impacts when including phases occurring before the product is shipped abroad, with the domestic transport and the processing phase contributing 24% and 20% respectively. This is demonstrated in Figure 10.

To get a better understanding of the definition *total environmental impacts,* if the impact category *Eutrophication* is taken as an example, it can be seen that the catching phase contributes to 90% of that impact category alone. When all impact categories assessed are summed to 100%, the relative contribution of the catching phase from all impact categories, as an example, is 56% of the total environmental impacts as mentioned above.

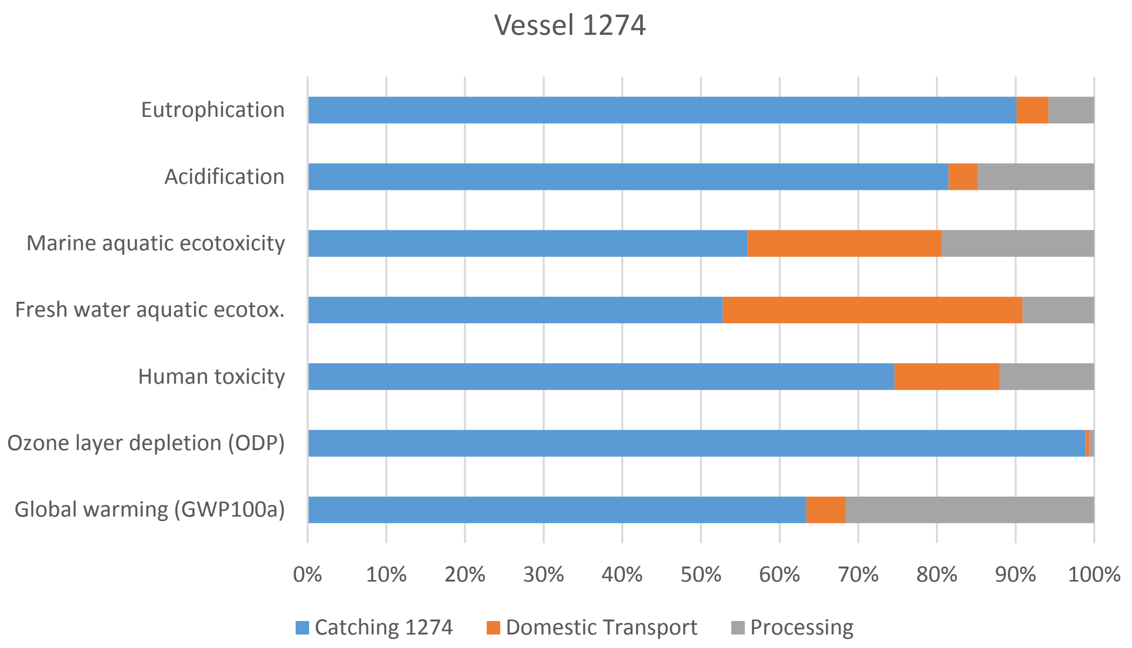

Figure 10. Characterized results from vessel 1274 showing the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 11 the carbon footprint of the catching, domestic transport and processing phases is shown. The total carbon footprint of the catching phase is 0,64 kg CO_2 eq. (equivalents), 0,05 kg CO_2 eq. for the domestic transport and 0,32 kg CO_2 eq. for the processing phase. The total amount of carbon footprint of these phases for vessel 1274 is 1,01 kg CO_2 eq.

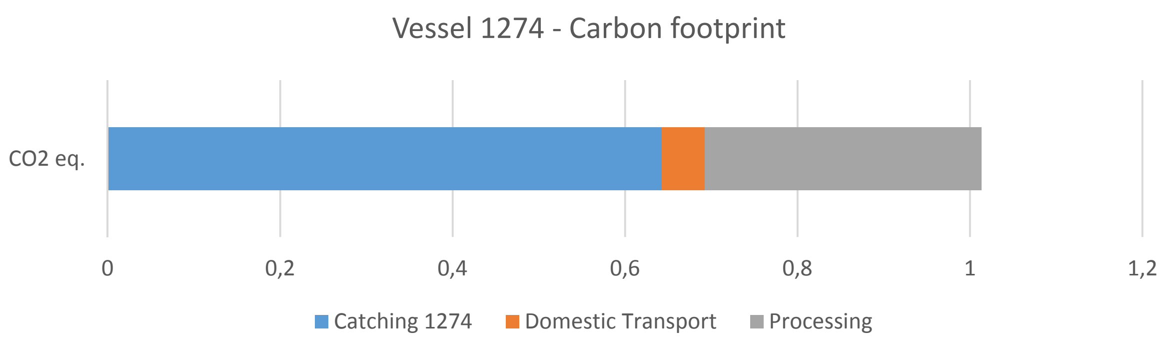

Figure 11. Carbon footprint of the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 12, international transport to the U.K by sea has been added, contributing 11,5% of the total environmental impacts, roughly 10% less than the domestic transport.

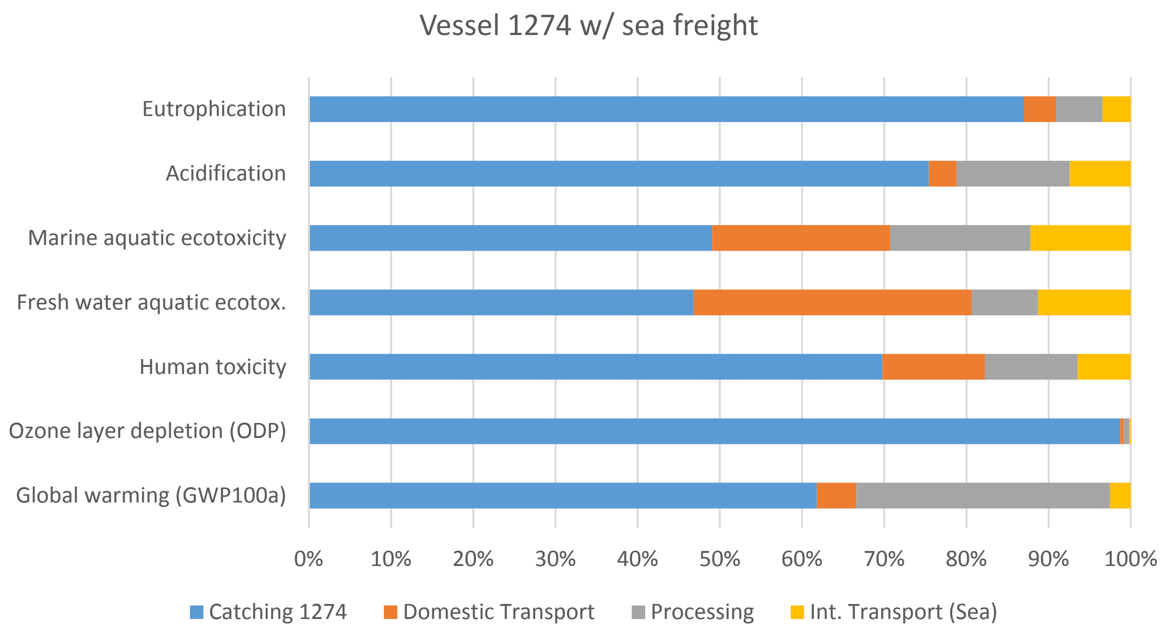

Figure 12. Figure 2. Characterized results from vessel 1274 showing the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

By adding international transport to the U.K by sea, only 0,026 kg CO_2 eq. are added to the total sum of carbon footprint, increasing it from 1,01 kg CO_2 eq. to 1,032 kg CO_2 eq.

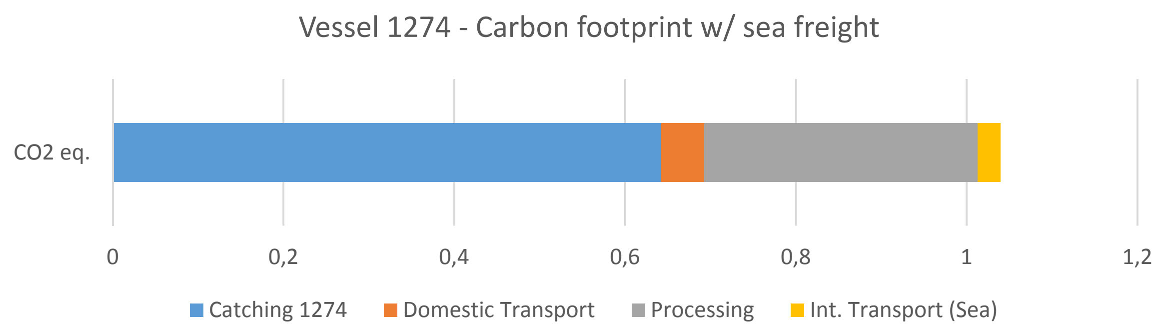

Figure 13. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

When air freight to the U.K is used instead of sea freight however, the picture changes dramatically. As can be seen in Figure 14 the air transport contributes to 65% of the total environmental impacts.

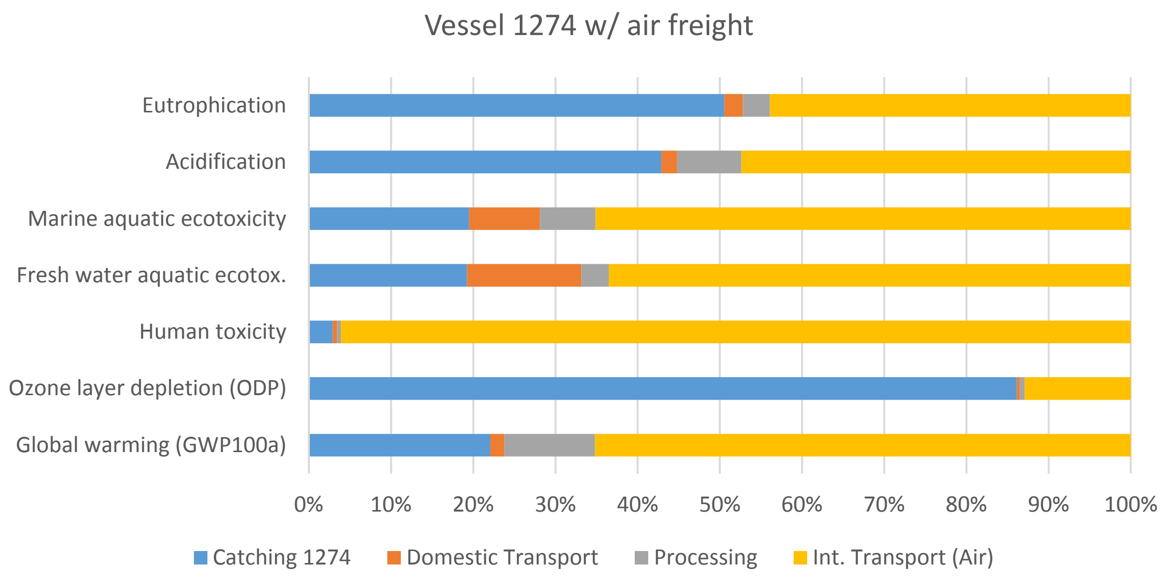

Figure 14. Characterized results from vessel 1274 showing the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

Figure 15 shows that the carbon footprint from the air freight alone is 1,89 kg CO_2 eq., increasing the total sum to 2,9 kg CO_2 eq.

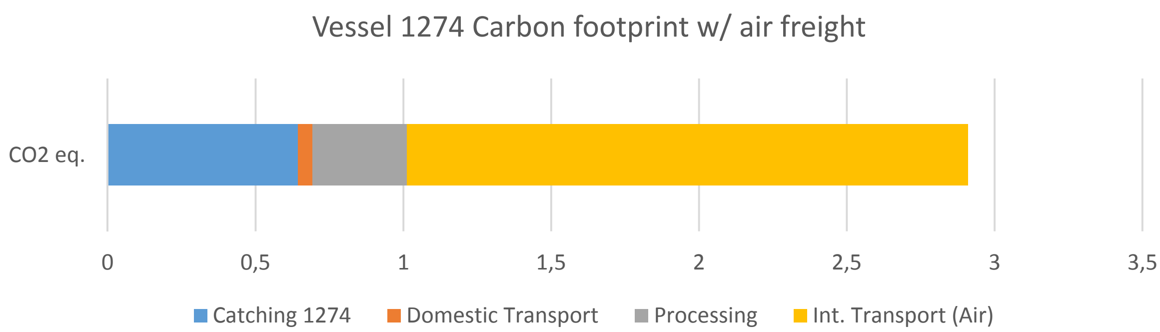

Figure 15. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

The massive contribution of the air freight increases the carbon footprint by a considerable amount, making the rather low carbon footprint from catching and processing small in comparison.

3.1.2 Vessel 1629 (Farsæll SH)

The results from vessel 1629 show that the catching phase contributes to 68% of the total environmental impacts when including phases occurring before the product is shipped abroad, with the domestic transport and the processing phase contributing 17,9% and 14,7% respectively. This is demonstrated in Figure 16.

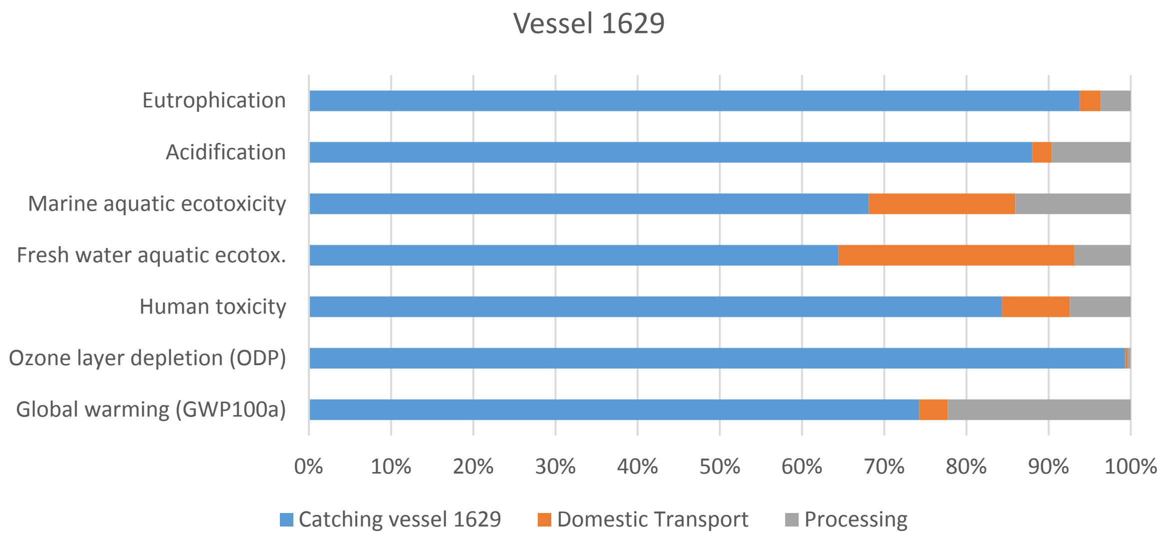

Figure 16. Characterized results from vessel 1629 showing the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 17 the carbon footprint of the catching, domestic transport and processing phases is shown. The total carbon footprint of the catching phase is 1,07 kg CO_2 eq. (equivalents), 0,04 kg CO_2 eq. for the domestic transport and 0,32 kg CO_2 eq. for the processing phase. The total amount of carbon footprint of these phases for vessel 1629 is 1,43 kg CO_2 eq.

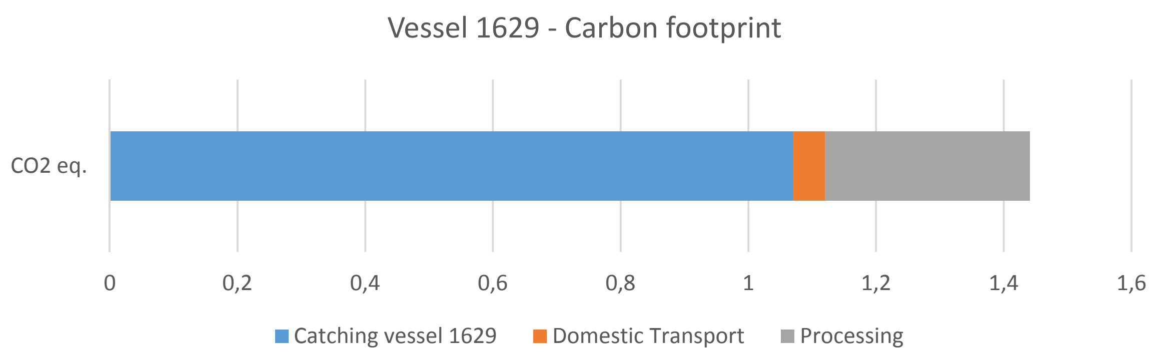

Figure 17. Carbon footprint of the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 18, international transport to the U.K by sea has been added, contributing 8,6% of the total environmental impacts.

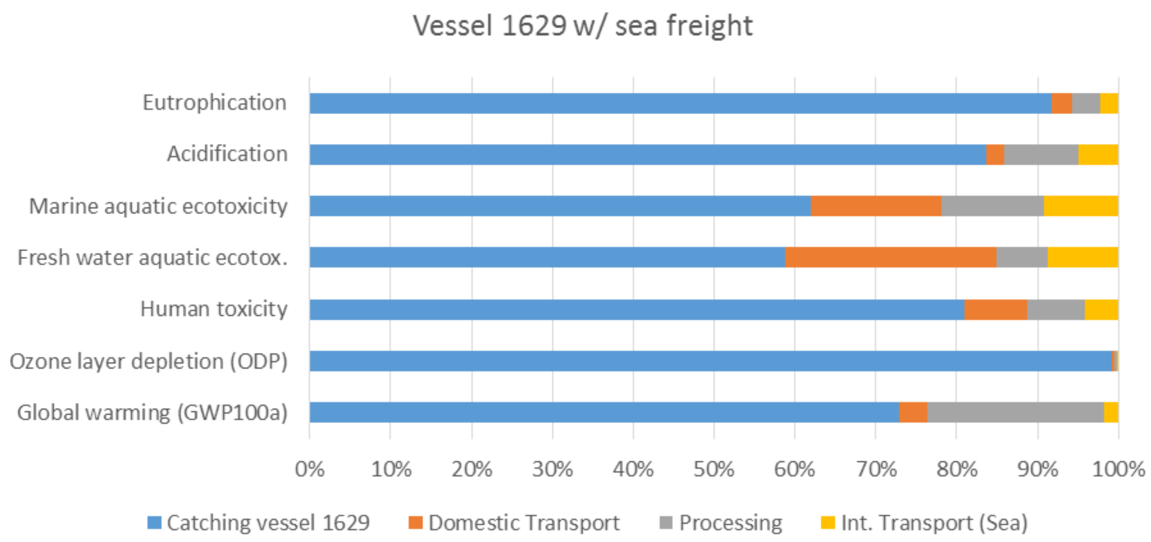

Figure 18. Characterized results from vessel 1629 showing the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

The international transport to the U.K by sea adds only 0,026 kg CO_2 eq. to the total sum of carbon footprint, increasing it from 1,43 kg CO_2 eq. to 1,456 kg CO_2 eq.

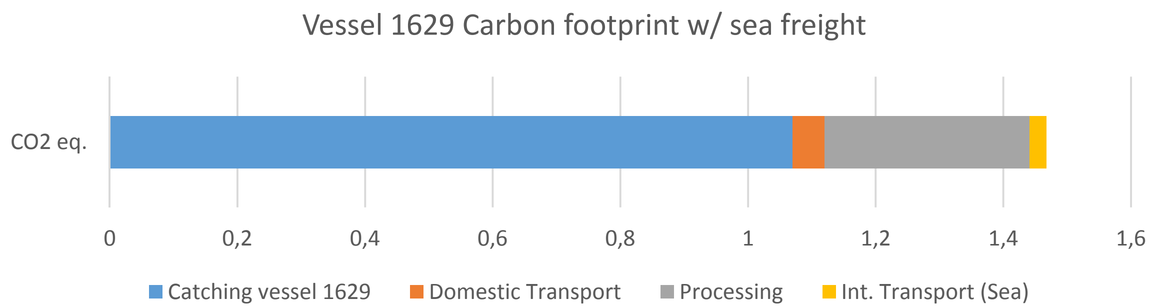

Figure 19. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

In Figure 20 the international transport to the U.K has been added instead of sea freight, contributing to 57% of the total environmental impacts.

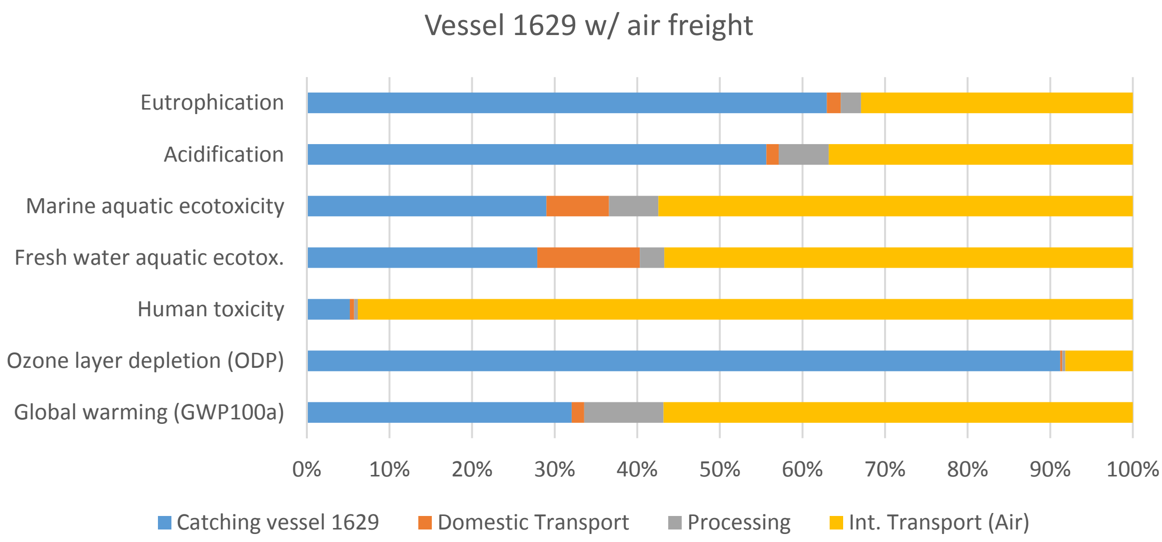

Figure 20. Characterized results from vessel 1629 showing the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

Figure 21 shows the total carbon footprint when the air freight has been added. The total carbon footprint is 3,33 kg CO_2 eq. from which 1,89 kg CO_2 eq. is caused the air transport.

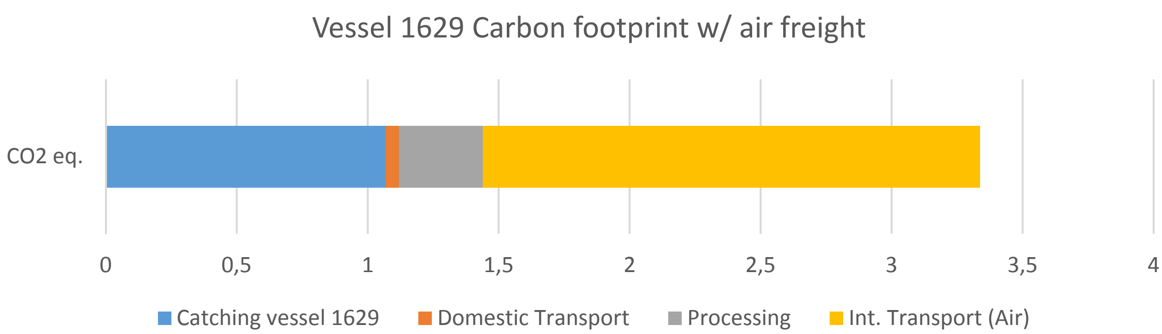

Figure 21. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

The air freight adds considerably to the total carbon footprint of the cod loins compared to the sea freight. In this case the air freighted cod loins have a 133% higher carbon footprint than the loins that are sea freighted to the UK.

3.1.3 Vessel 1472 (Klakkur SH)

The results from vessel 1472 show that the catching phase contributes to 66% of the total environmental impacts when including phases occurring before the product is shipped abroad, with the domestic transport and the processing phase contributing 18,5% and 15,5% respectively. This is demonstrated in Figure 22.

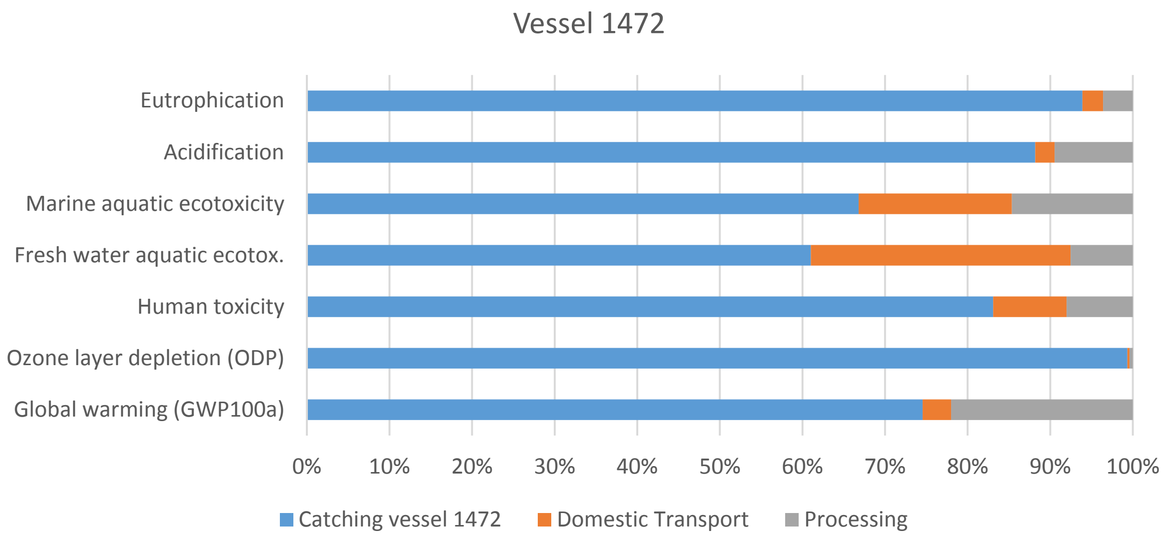

Figure 22. Characterized results from vessel 1472 showing the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

The carbon footprint of the catching, domestic transport and processing phases is shown in Figure 23. The total carbon footprint of the catching phase is 1,09 kg CO_2 eq. (equivalents), 0,04 kg CO_2 eq. for the domestic transport and 0,32 kg CO_2 eq. for the processing phase. The total carbon footprint of these phases for vessel 1472 is therefore 1,45 kg CO_2 eq.

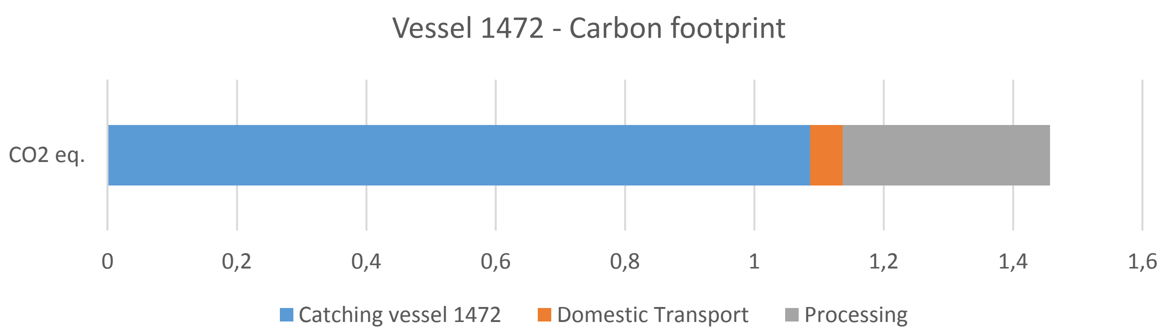

Figure 23. Carbon footprint of the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 24, the international transport to the U.K by sea has been added, contributing 9,5 % of the total environmental impacts and adding only 0,026 kg CO_2 eq. to the total carbon footprint, as can be seen in Figure 25.

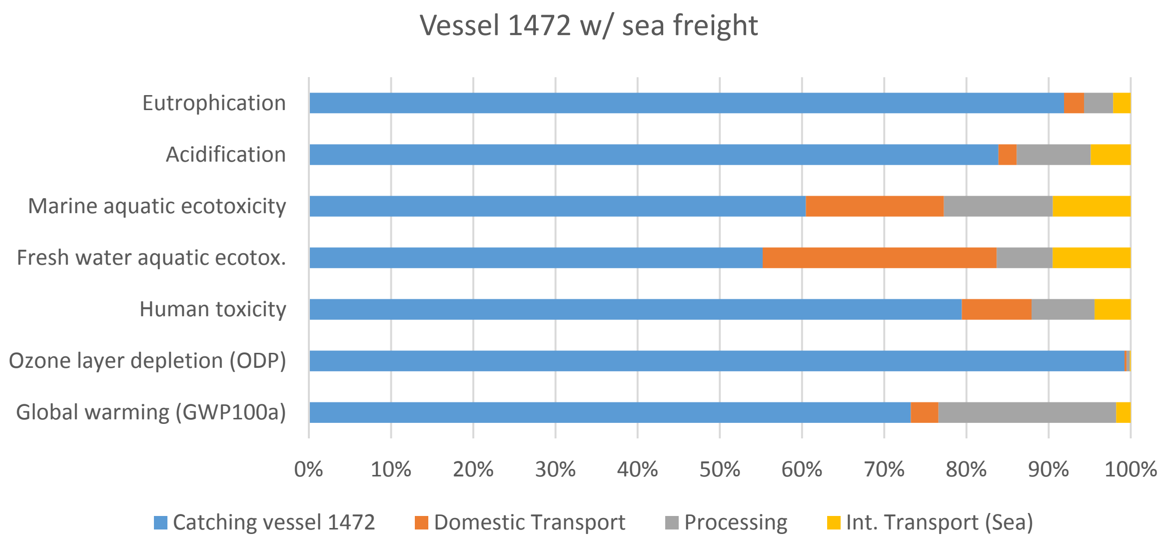

Figure 24. Characterized results from vessel 1472 showing the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

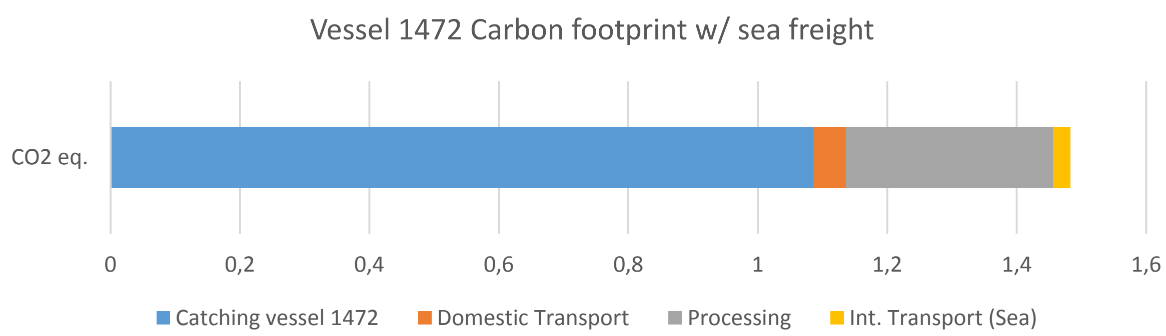

Figure 25. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

When adding air freight to the U.K instead of sea freight the total carbon footprint changes dramatically, as seen in Figure 26. The air transport contributes to 58,5% of the total environmental impacts.

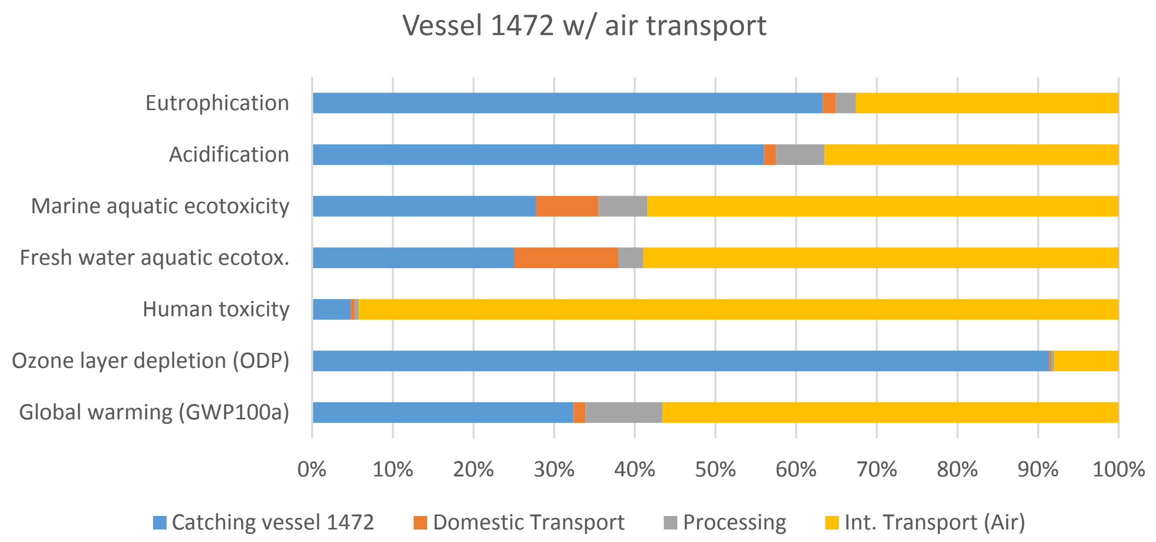

Figure 26. Characterized results from vessel 1472 showing the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

Figure 27 shows the increase in carbon footprint when adding the air freight to the U.K. The air freight alone adds 1,89 kg CO_2 eq., raising the total sum to 3,34 kg CO_2 eq.

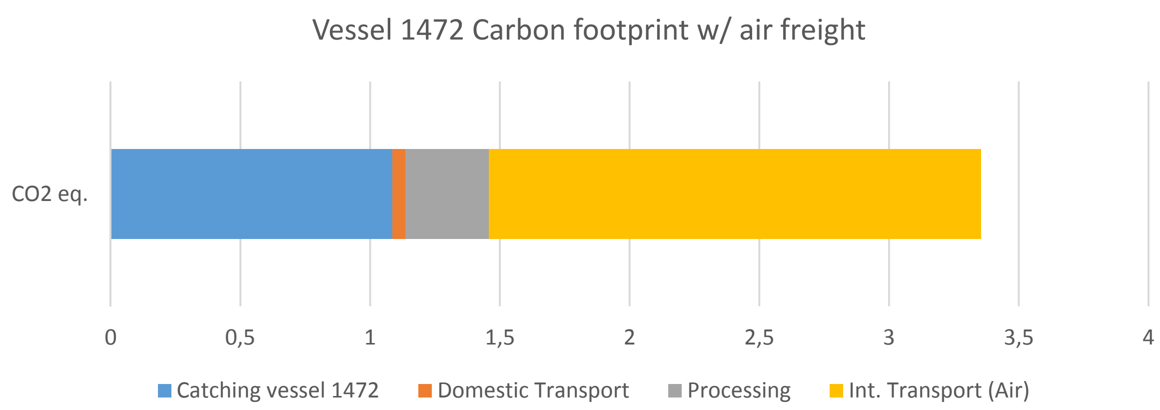

Figure 27. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

The importance of having as low carbon footprint from the catching and processing phases as possible shows when the air freight is added, since the carbon footprint from the air freight is the same for all the vessels.

3.2 Long-liners

Four long liners provided data for the LCA, one large long-liner with auto-line system and one large long-liner using hand-baited line and two small coastal long-liners using hand-baited line. The two larger vessels stay out at sea for 3-5 days per fishing trip, but the small coastal vessels land their catch daily.

3.2.1 Vessel 1527 (Brimnes BA)

The results from vessel 1527 show that the catching phase contributes to 41% of the total environmental impacts when including phases occurring before the product is shipped abroad, with the domestic transport and the processing phase contributing 33% and 26,5% respectively, as shown in Figure 28.

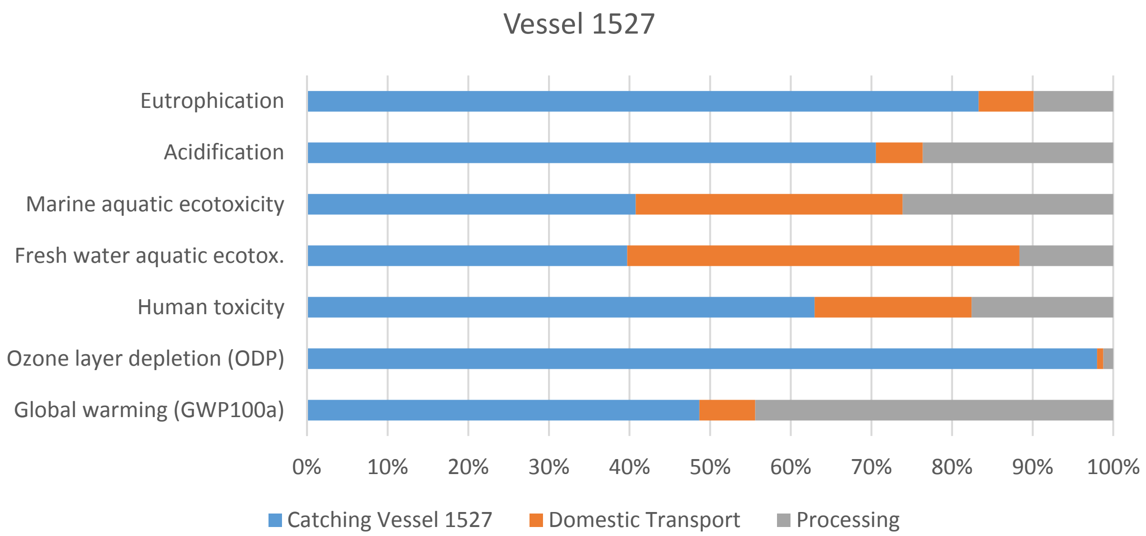

Figure 28. Characterized results from vessel 1527 showing the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 29 the carbon footprint of the catching, domestic transport and processing phases is shown. The total carbon footprint of the catching phase is 0,35 kg CO_2 eq. (equivalents), 0,05 kg CO_2 eq. for the domestic transport and 0,32 kg CO_2 eq. for the processing phase. The total carbon footprint of these phases for vessel 1527 is 0,72 kg CO_2 eq.

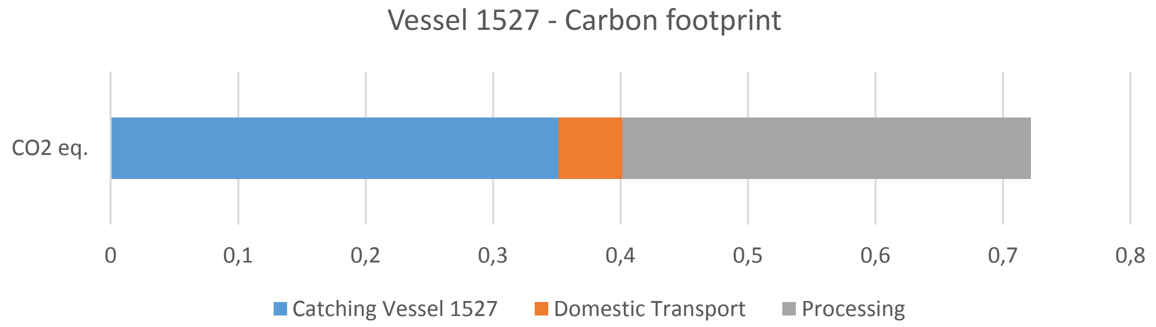

Figure 29. Carbon footprint of the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 30, international transport to the U.K by sea has been added, contributing 15,6% of the total environmental impacts.

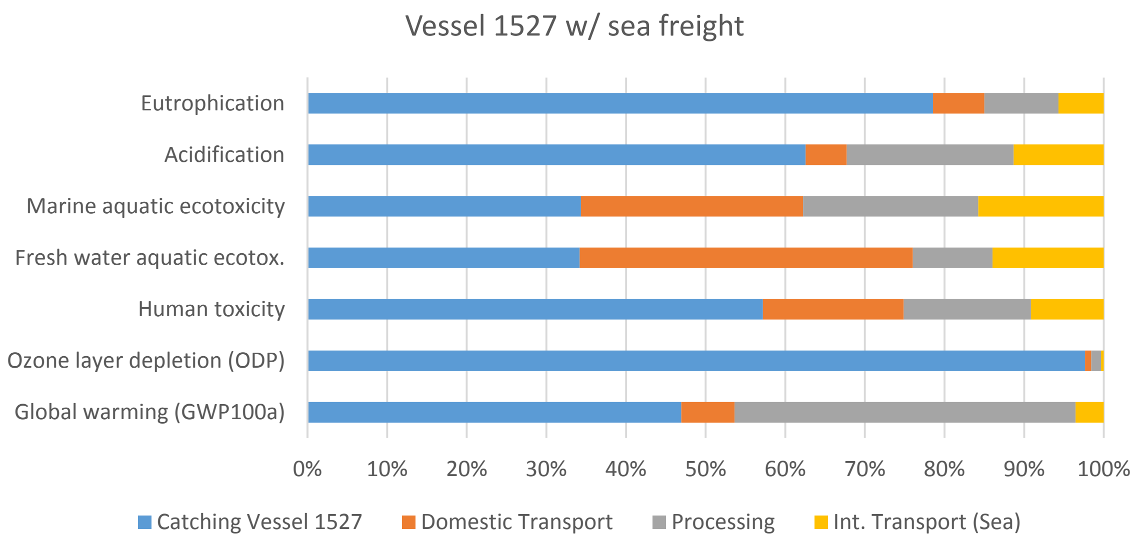

Figure 30. Characterized results from vessel 1527 showing the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

By adding international transport to the U.K by sea, only 0,026 kg CO_2 eq. are added to the total sum of carbon footprint, increasing it from 0,72 kg CO_2 eq. to 0,746 kg CO_2 eq. as shown in Figure 31.

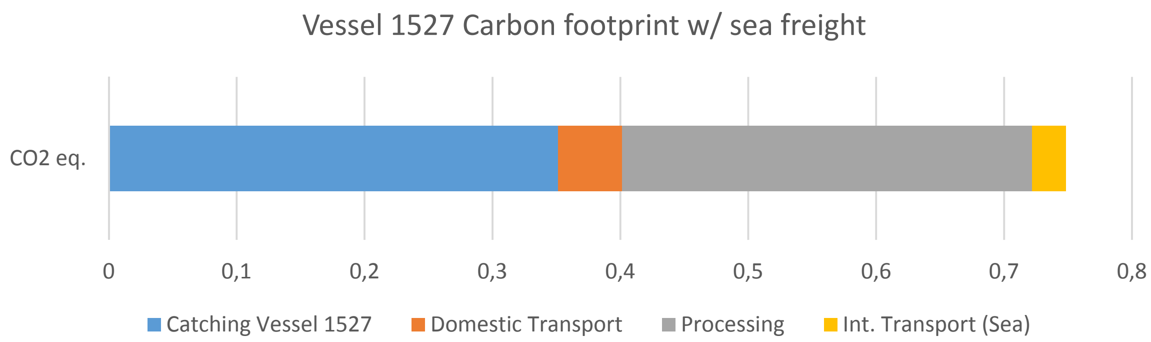

Figure 31. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

The air freight for vessel 1527 contributes to 71,8% of the total environmental impacts as shown in Figure 32.

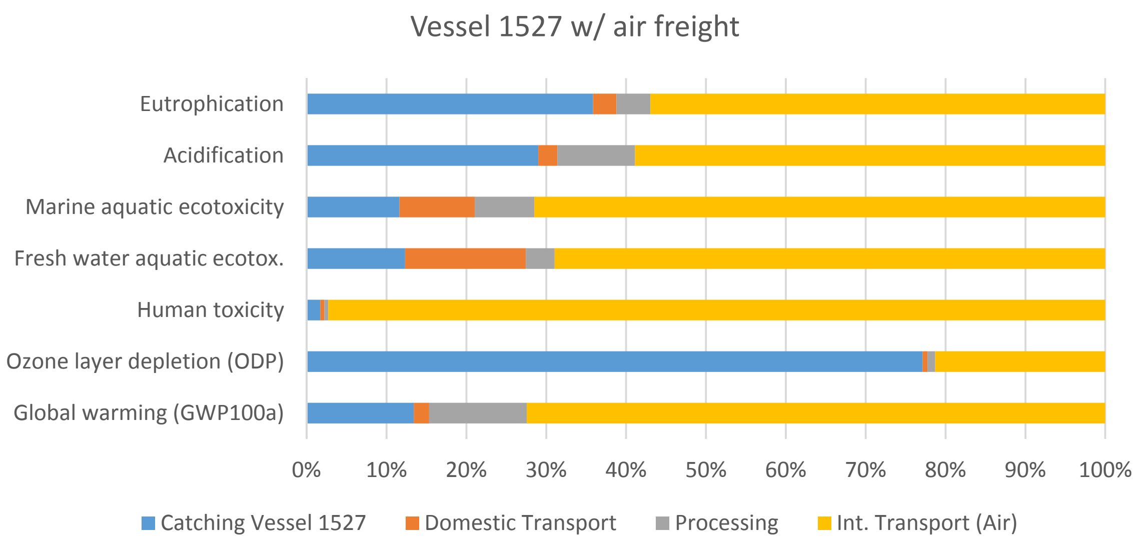

Figure 32. Characterized results from vessel 1527 showing the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

By adding the air freight, the total carbon footprint increases to a total of 2,61 CO_2 eq. as can be seen in Figure 33.

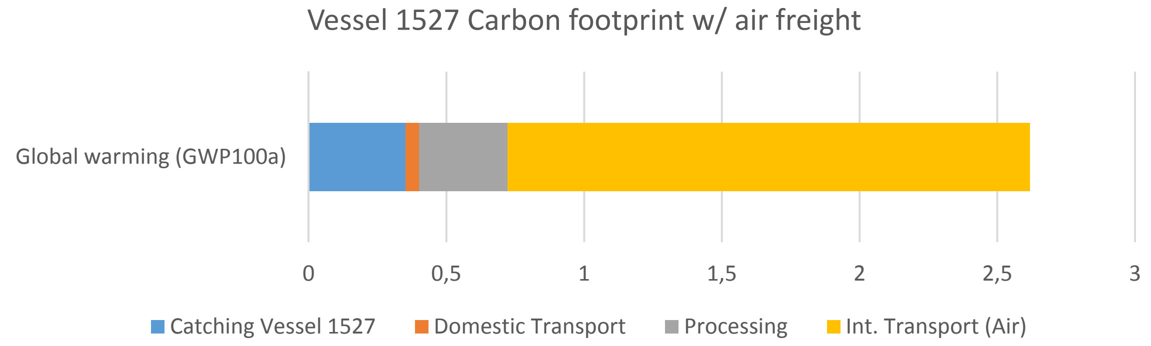

Figure 33. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

The air freight adds 1,89 CO_2 eq. to the carbon footprint. The air transport is therefore responsible for over 72% of the products total carbon footprint.

3.2.2 Vessel 1591 (Núpur BA)

The results from vessel 1591 show that the catching phase contributes to 44% of the total environmental impacts when including phases occurring before the product is shipped abroad, with the domestic transport and the processing phase contributing 30,7% and 24,8% respectively. This is demonstrated in Figure 34.

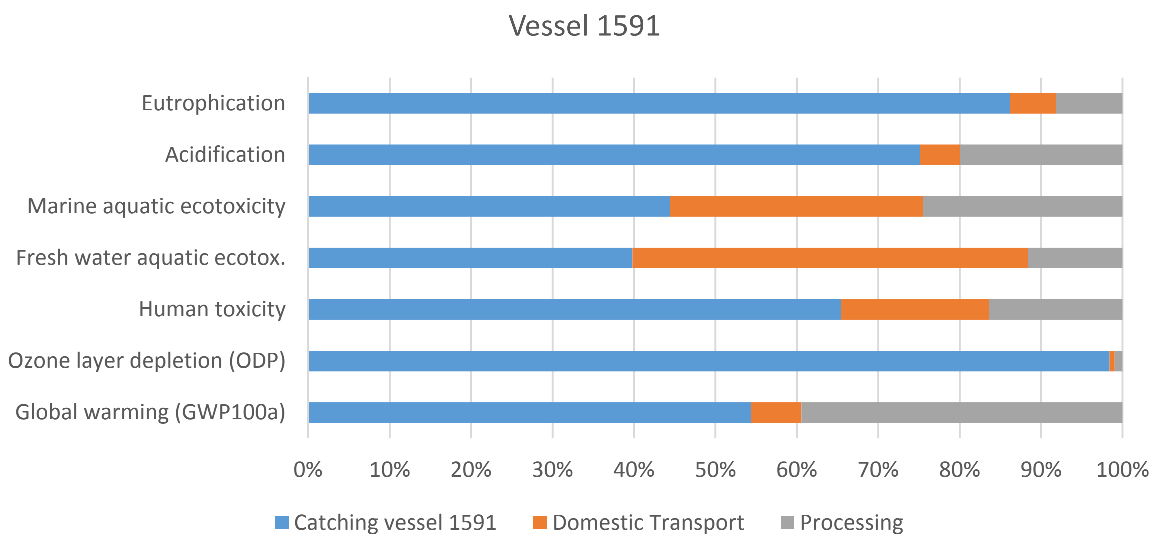

Figure 34. Characterized results from vessel 1591 showing the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 35 the carbon footprint of the catching, domestic transport and processing phases is shown. The total carbon footprint of the catching phase is 0,44 kg CO_2 eq. (equivalents), 0,05 kg CO_2 eq. for the domestic transport and 0,32 kg CO_2 eq. for the processing phase. The total carbon footprint of these phases for vessel 1591 is 0,81 kg CO_2 eq.

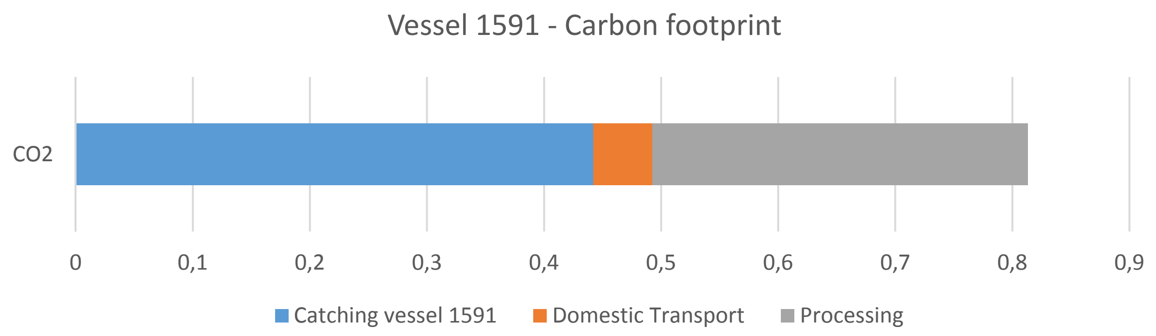

Figure 35. Carbon footprint of the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 36 international transport to the U.K by sea has been added, contributing 14,7% of the total environmental impacts.

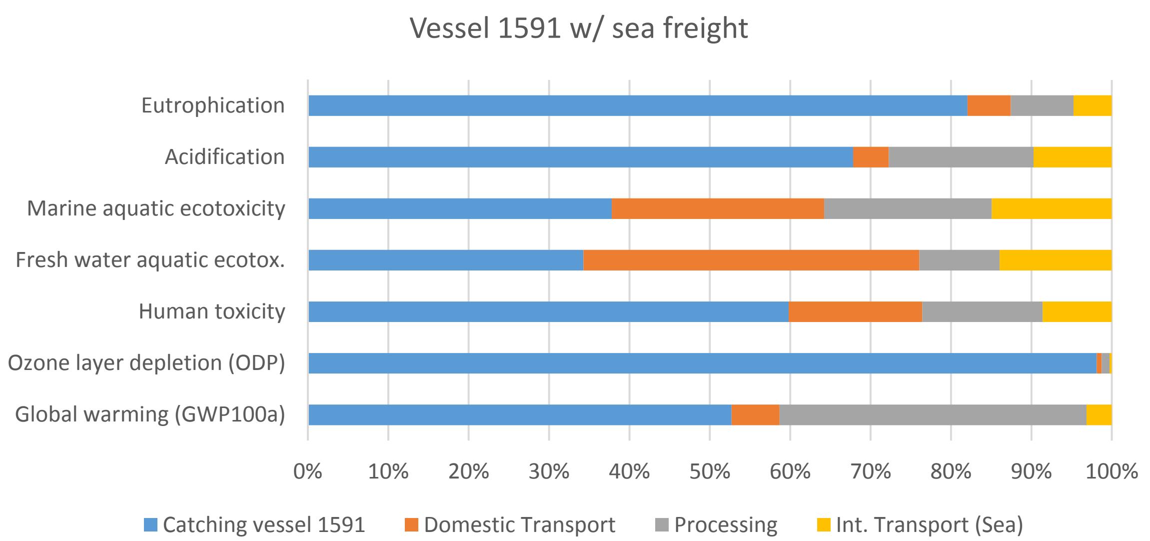

Figure 36. Characterized results from vessel 1591 showing the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

Adding international transport to the U.K by sea increases the total carbon footprint of the cod loins by only 0,026 kg CO_2 eq. increasing it from 0,81 kg CO_2 eq. to 0,836 kg CO_2 eq.

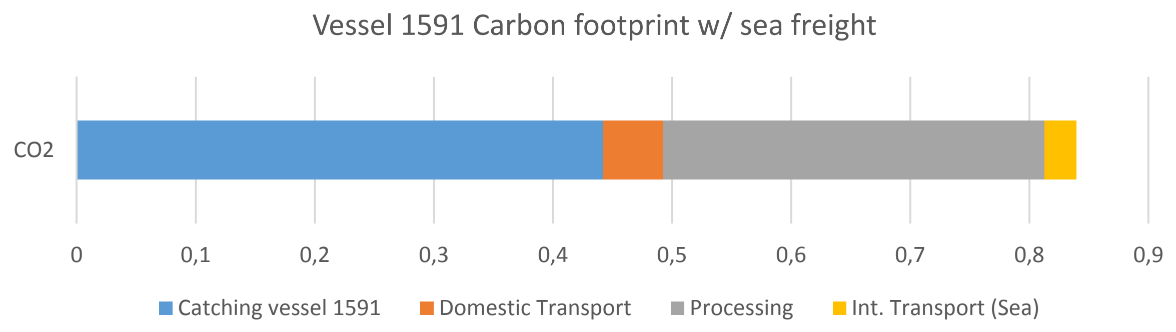

Figure 37. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

Transportation by air freight instead of sea freight however adds significantly to the products total carbon footprint, as can be seen in Figure 38. The air transport contributes to 70% of the total environmental impacts.

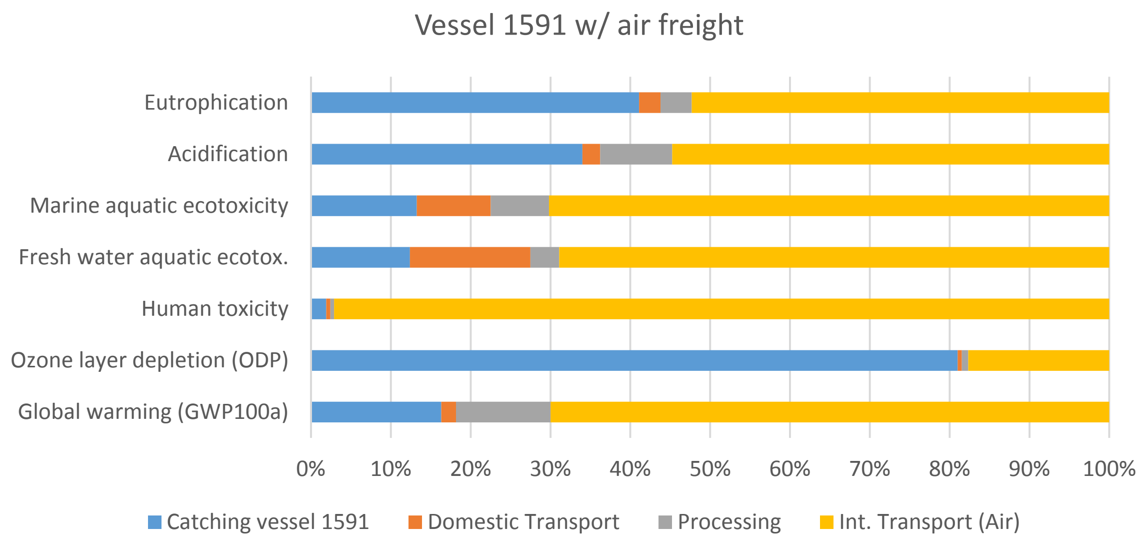

Figure 38. Characterized results from vessel 1591 showing the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

Adding the air freight to the equation increases to a total carbon footprint of the cod loins to 2,7 kg CO_2 eq./kg, where the international transport phase is responsible for 1,89 kg CO2 eq. or 70%, as can be seen in Figure 39.

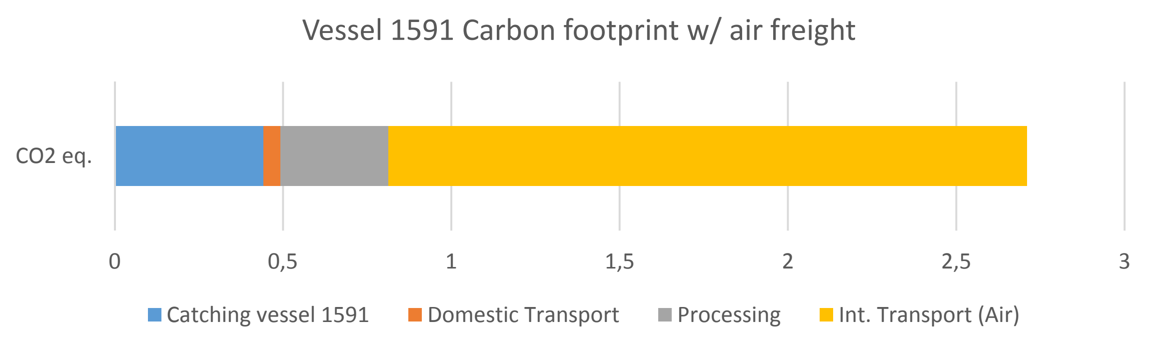

Figure 39. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

The carbon footprints from the catching and processing phases, as well as from the transportation phases for the cod loins produced from the catch of vessel 1591 are very similar to those caught by vessel 1527. Both vessels are owned by the same company, processed in the same processing plant and transported through the same transportation routes.

3.2.3 Vessel 2631 (Gestur Kristinsson ÍS)

The results from vessel 2631 show that the catching phase contributes to 35% of the total environmental impacts when including phases occurring before the product is shipped abroad, with the domestic transport and the processing phase contributing 36% and 29% respectively. This is demonstrated in Figure 40.

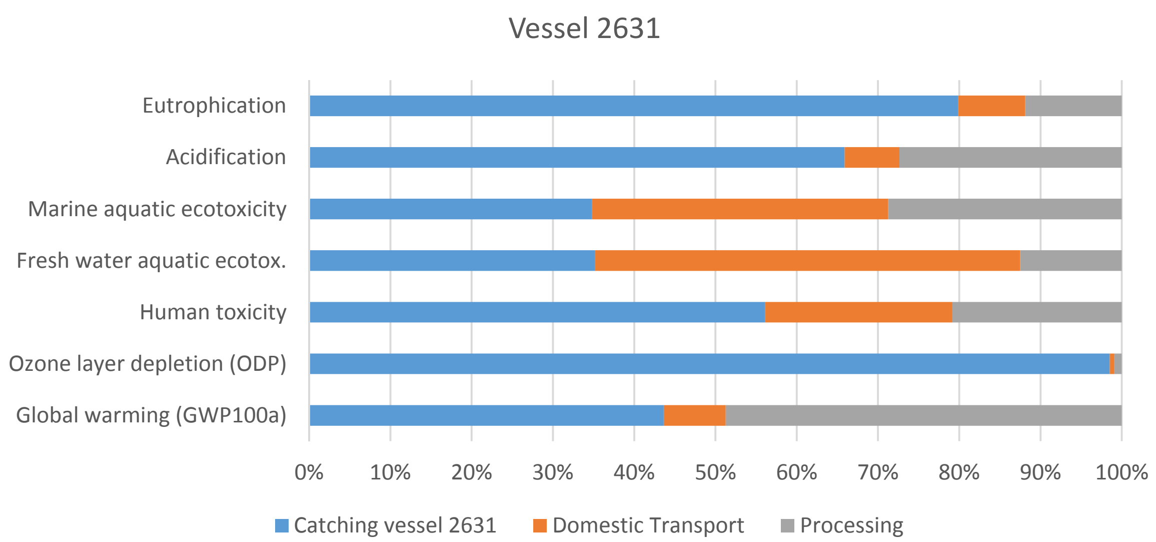

Figure 40. Characterized results from vessel 2631 showing the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 41 the carbon footprint of the catching, domestic transport and processing phases is shown. The total carbon footprint of the catching phase is 0,287 kg CO_2 eq. (equivalents), 0,06 kg CO_2 eq. for the domestic transport and 0,32 kg CO_2 eq. for the processing phase. The total carbon footprint of these phases for vessel 2631 is 0,657 kg CO_2 eq.

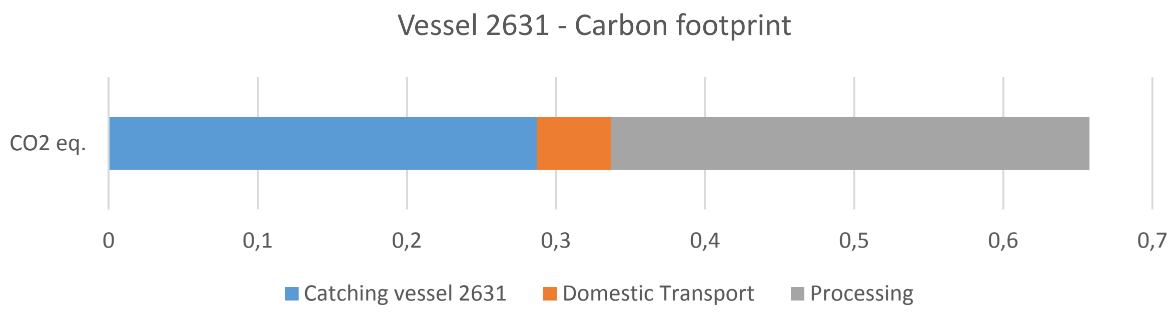

Figure 41. Carbon footprint of the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 42, international transport to the U.K by sea has been added, contributing 16,9% of the total environmental impacts.

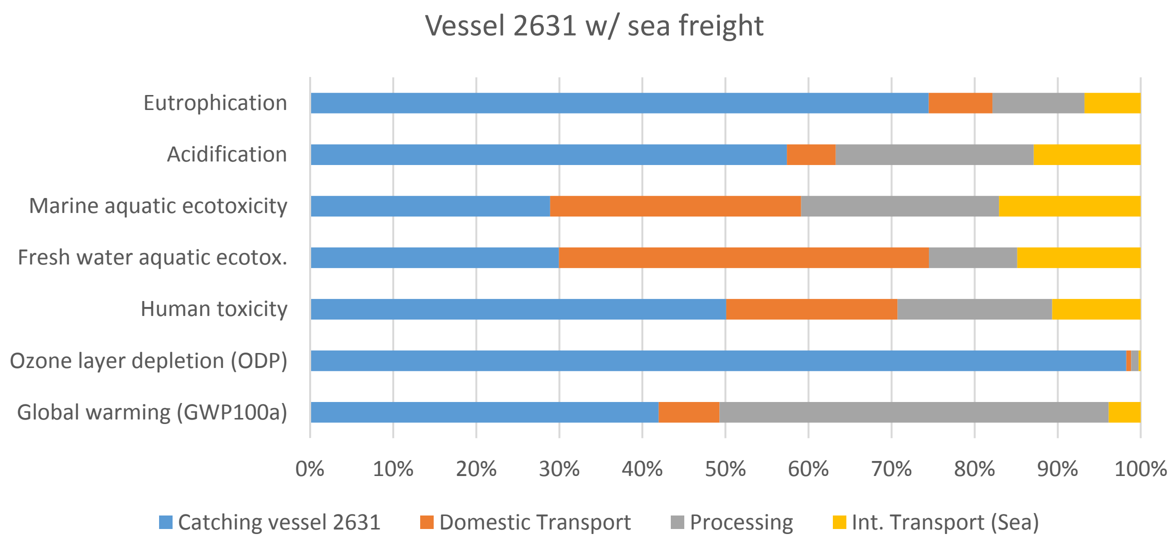

Figure 42. Characterized results from vessel 2631 showing the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

By adding the international transport to the U.K by sea, the carbon footprint increases to 0,683 kg CO_2 eq. as can be seen in Figure 43.

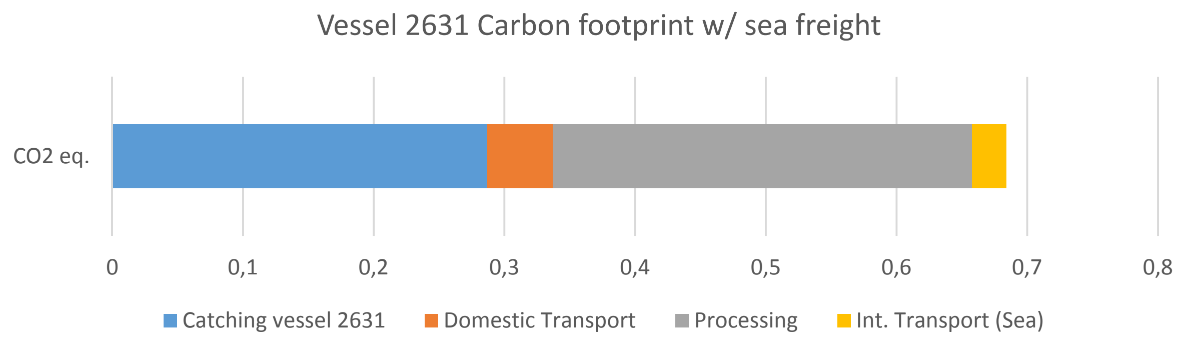

Figure 43. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

If the cod loins are transported to the UK by air freight the environmental impact increases significantly, as the air transport contributes to 73,8% of the products total environmental impacts, which can be seen in Figure 44.

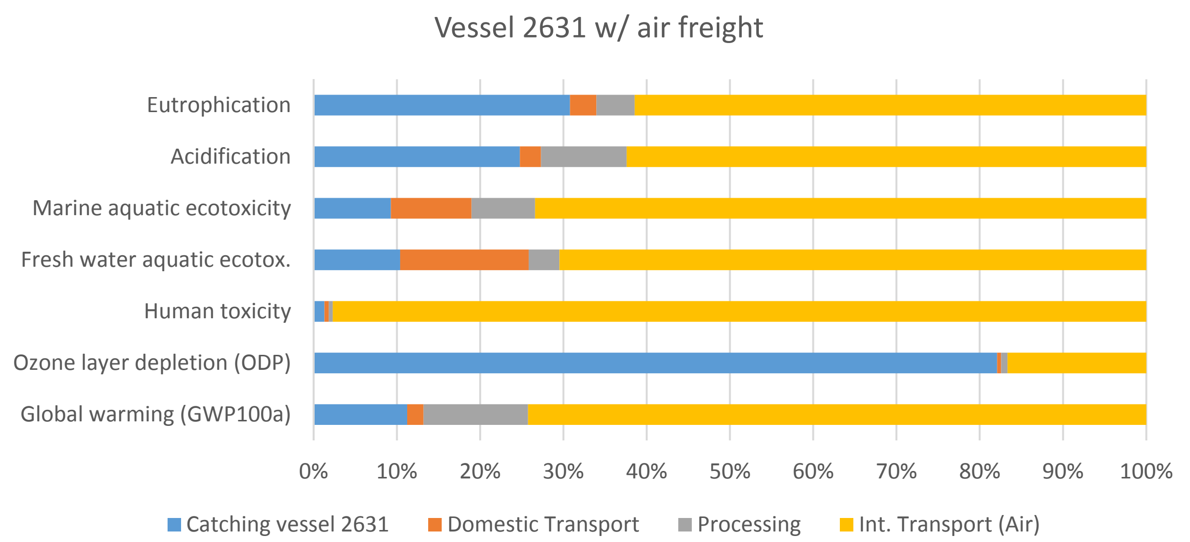

Figure 44. Characterized results from vessel 2631 showing the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

By adding the air freight, the total carbon footprint of the cod loins increases to 2,55 CO_2 eq./kg loins, as shown in Figure 45.

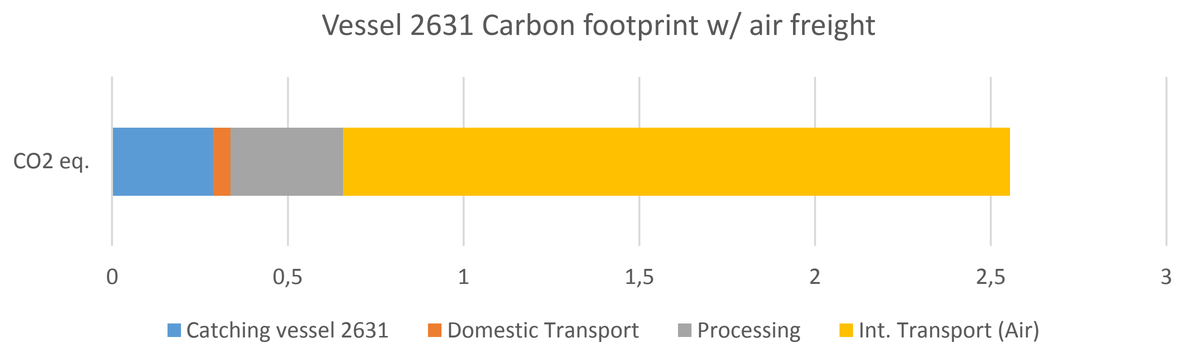

Figure 45. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

Due to low carbon emissions during the catching, processing and domestic transportation phases the high emissions associated with air transport become even more startling than usually, as the air freight contributes to 74,5% of the total carbon footprint of the cod loins whilst the other phases combined contribute only 25,5%.

3.2.4 Vessel 2614 (Kristján ÍS)

The results from vessel 2614 show that the catching phase contributes to 36,8% of the total environmental impacts when including phases occurring before the product is shipped abroad, with the domestic transport and the processing phase contributing 35% and 28,2% respectively. This is demonstrated in Figure 46.

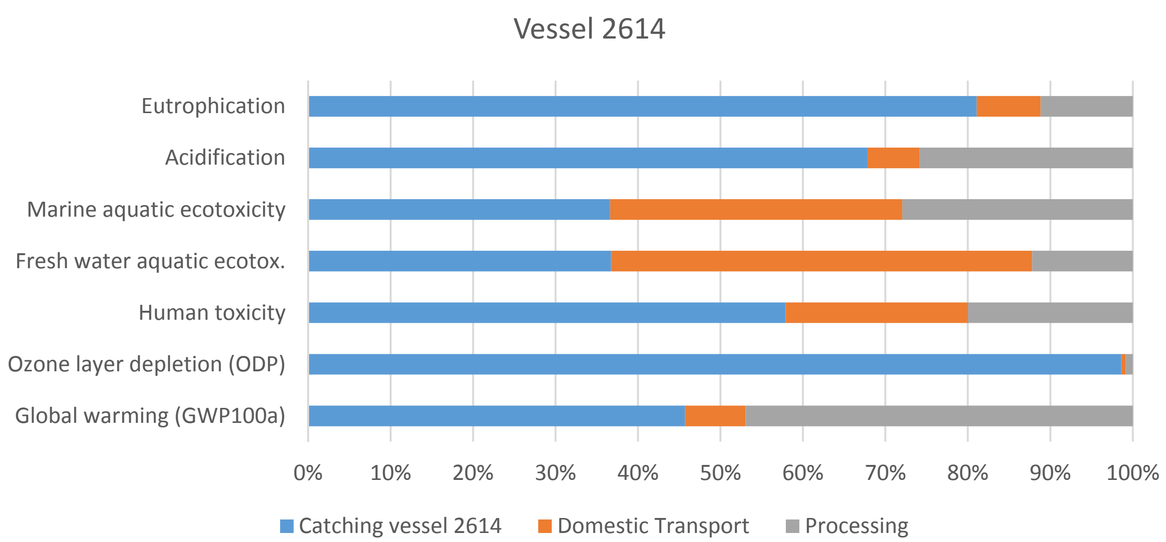

Figure 46. Characterized results from vessel 2614 showing the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 47 the carbon footprint of the catching, domestic transport and processing phases is shown. The total carbon footprint of the catching phase is 0,312 kg CO_2 eq. (equivalents), 0,06 kg CO_2 eq. for the domestic transport and 0,32 kg CO_2 eq. for the processing phase. The total amount of carbon footprint of these phases for vessel 2614 is 0,682 kg CO_2 eq.

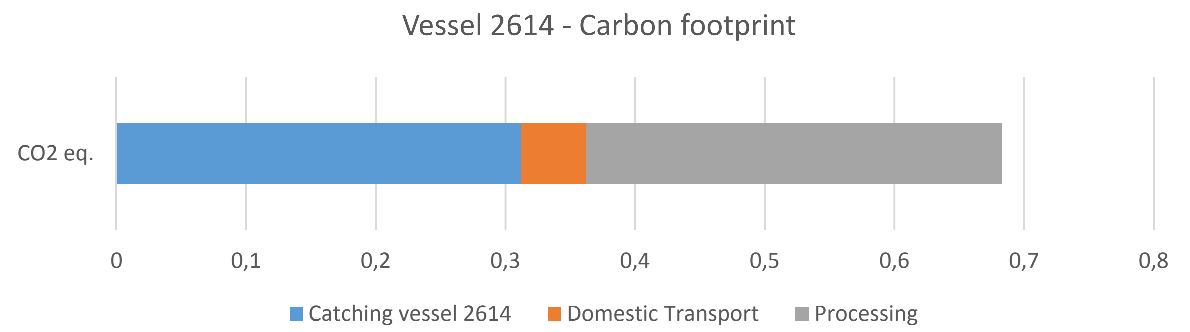

Figure 47. Carbon footprint of the catching, domestic transport and processing phases. Showed in kg CO_2/kg product

In Figure 48, international transport to the U.K by sea has been added, contributing 16,5% of the total environmental impacts.

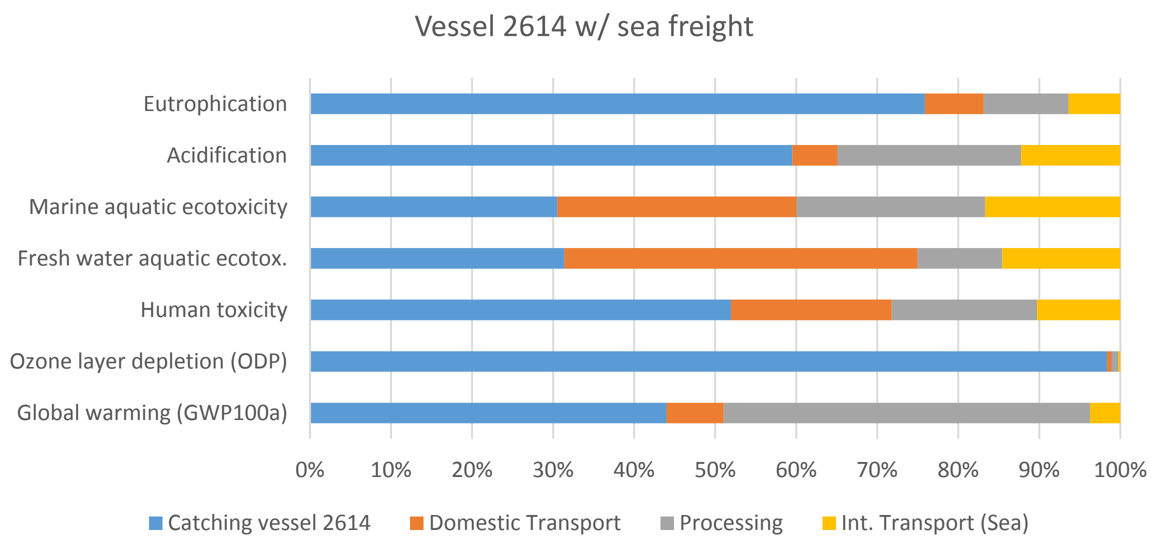

Figure 48. Characterized results from vessel 2614 showing the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

By adding international transport to the U.K by sea, the carbon footprint increases to 0,709 kg CO_2 eq./ kg product, as can be seen in Figure 49.

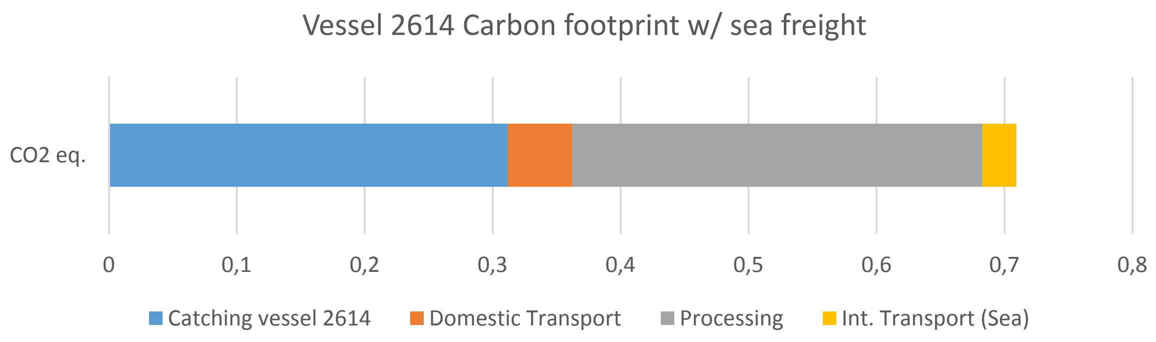

Figure 49. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by sea phases. Showed in kg CO_2/kg product

If the cod loins are transported to the UK by air freight instead of sea freight the total environmental impact changes significantly, as can be seen in Figure 50. The air freight alone contributes to 73% of the total environmental impacts.

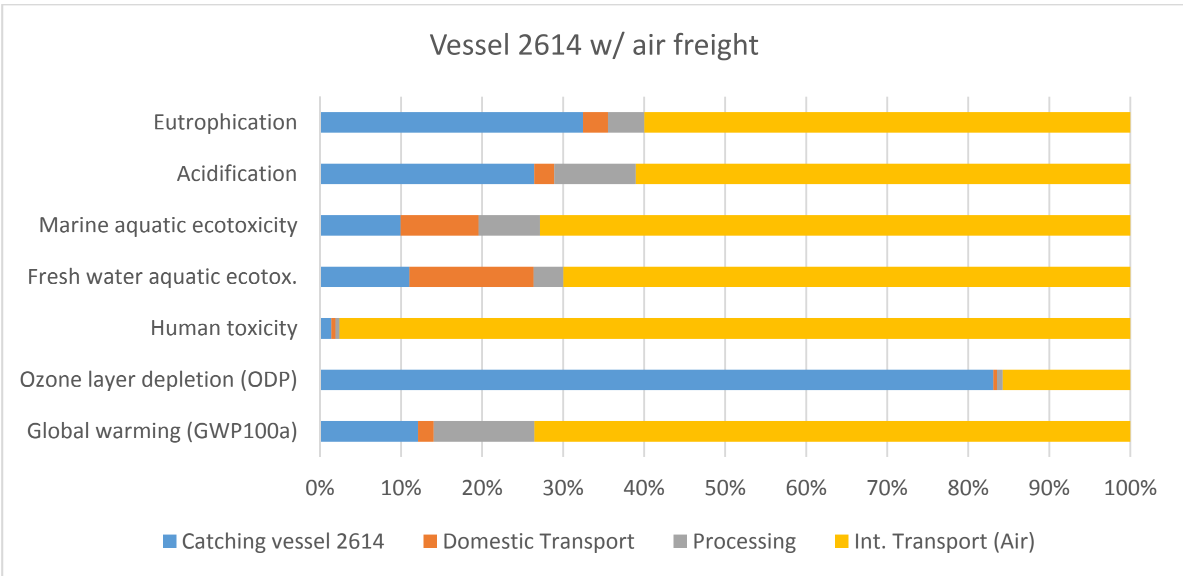

Figure 50. Characterized results from vessel 2614 showing the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

Figure 51 demonstrates the significance of the air freight in regards to the total carbon footprint of the product. The total carbon footprint of air freighted cod loins is 2,579 kg CO_2 eq/kg loin, compared to 0,709 kg CO_2 eq. for sea freighted loins.

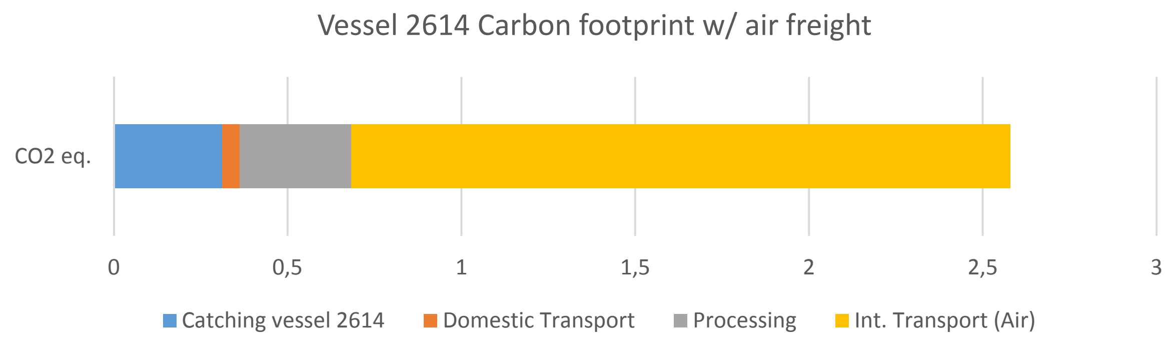

Figure 51. Carbon footprint of the catching, domestic transport, processing and international transport to the U.K by air phases. Showed in kg CO_2/kg product

The catching, domestic transport and processing phases only contribute to 26,7% of the total carbon footprint with air freight.

The carbon footprints from the catching and processing phases, as well as from the transportation phases for the cod loins produced from the catch of vessel 2614 are very similar to those caught by vessel 2631. Both vessels are similar in size, using identical fishing gear and catching in the same fishing grounds. They are also owned by the same company, processed in the same processing plant and transported through the same transportation routes.

3.3 Comparison

In previous chapters the environmental impacts of the functional unit with both sea and air freight has been analysed from both trawlers and long-liners. It is useful and necessary to compare the results from each group to get a better understanding of its meaning. Furthermore, comparison with similar studies can put the results in perspective, but with extreme caution as explained further in chapter 4.3.3.

3.3.1 Comparison of transports

Figure 52 shows the comparison of different transport modes to the U.K and Switzerland.

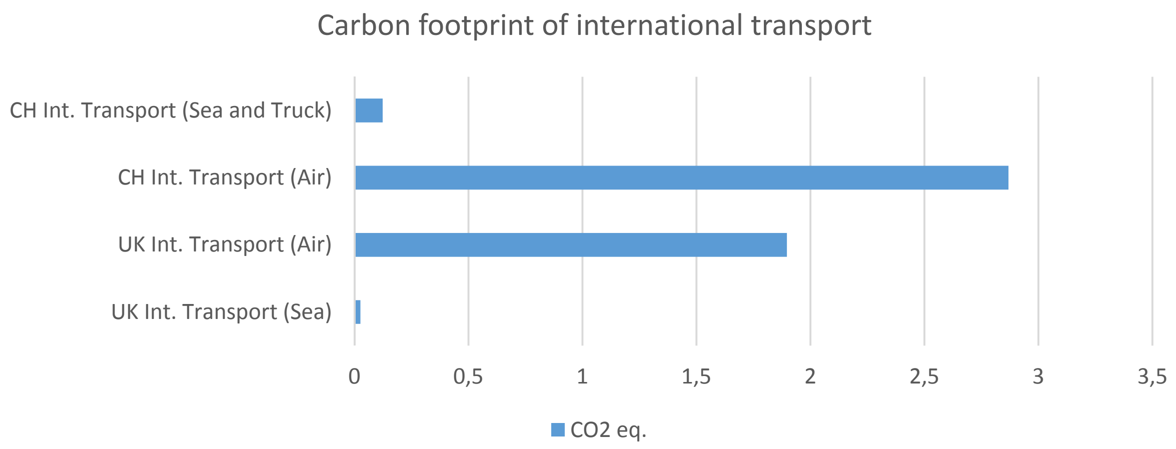

Figure 52. Comparison of the carbon footprint of different transport modes. Showed in kg CO_2/kg product

All modes are transporting 1 kg for the distance required. Note that other processes are not included.

3.3.2 Comparison of vessels – Carbon footprint

Figure 53 shows the comparison of carbon footprint for 1 kg of cod loin between all vessels assessed. The figure only shows the catching phase.

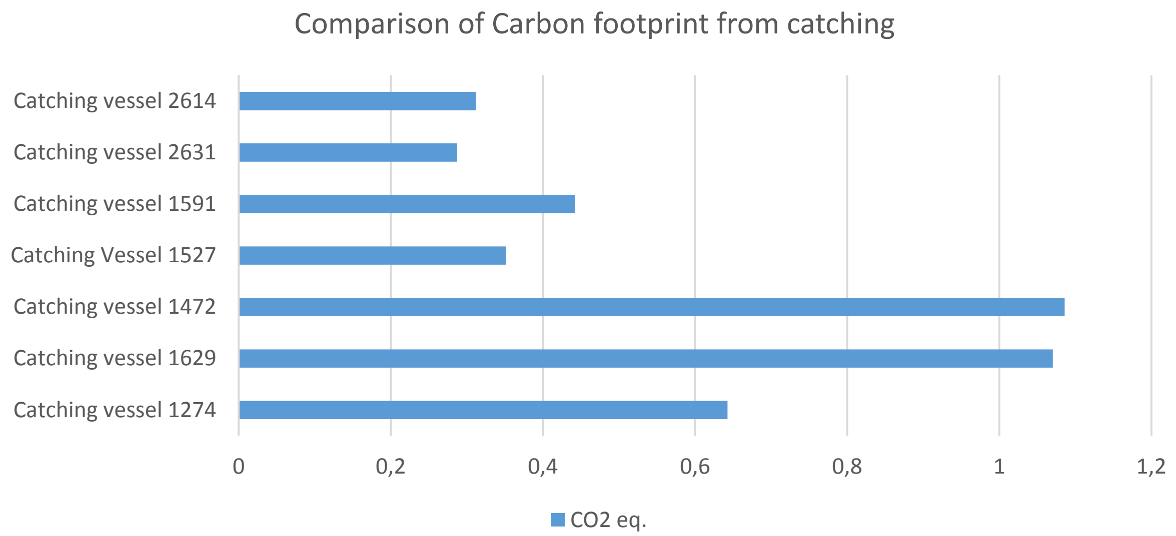

Figure 53. Comparison of carbon footprint of the catching phase between the vessels assessed. Showed in kg CO_2/kg product

In Figure 54, the full life cycle of the functional unit is included, that is, 1 kg of cod loin, processed and transported to the U.K by sea and air and to Switzerland by air. In addition, transport from Reykjavík to Rotterdam by sea and from Rotterdam to Switzerland by truck is included. It can be seen that the carbon footprint of the functional unit shipped by air to U.K is well above 2,5 – 3 kg CO_2 eq. for all vessels, opposed to when the functional unit is shipped by sea to the U.K the range is 0,6 – 1,5 kg CO_2 eq./ functional unit.

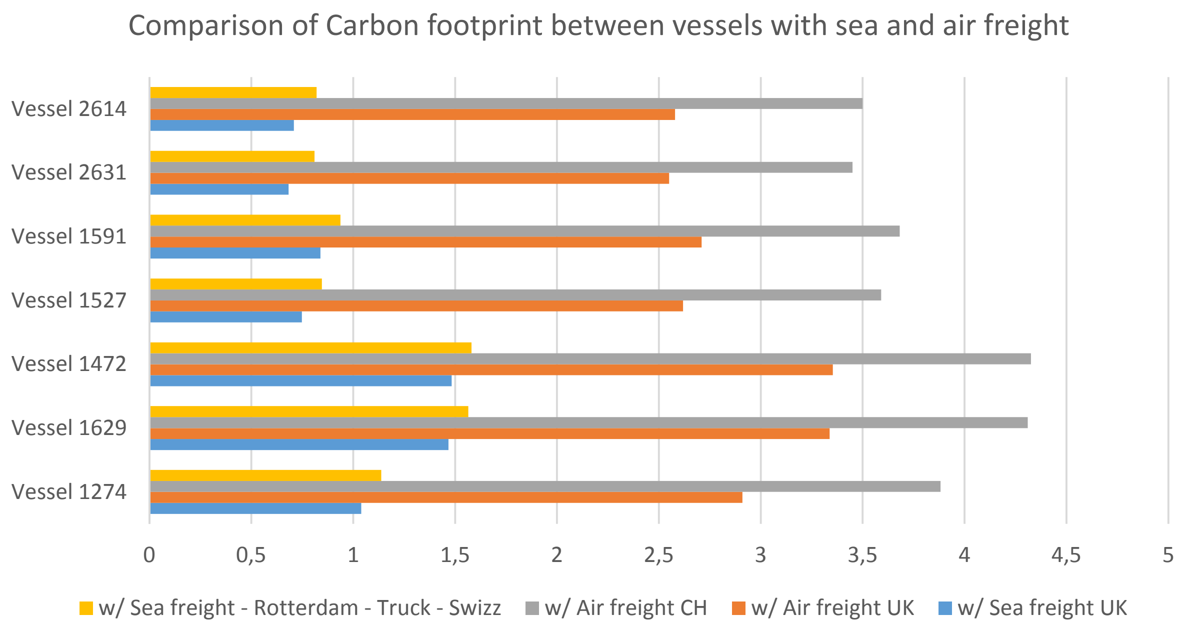

Figure 54. Comparison of carbon footprint between the vessels assessed – including full functional unit with different transport modes. Showed in kg CO_2/kg product.

The total carbon footprint of the cod loins can be severally reduced by transporting them to Switzerland by sea freight to Rotterdam and by truck the rest of the way, instead of sending them by air freight. This is though a transportation route that takes close to five days, which effects the shelf-life of the product and has therefore to be taken into consideration when doing such comparison.

3.3.3 Comparison with similar studies – Carbon footprint

The selected system boundaries for a production system in LCA's often do not include the overall life cycle of the product, which would apply to this study, since the consumption and final disposal was not taken into account. In the same manner, sometimes all environmental impact categories of any given suite are not included, purposely or not, and the choices of impact assessment methods differ from study to study. The point is, that when comparing LCA studies, one has to be very careful to compare the methods used. Generally speaking, no two studies use exactly the same parameters or system boundaries, which makes comparison not 100% accurate. With that being said, Figure 55 shows the average results from this study compared to various food products from Winther et al. (2009) and Ytrestøyl et al. (2010).

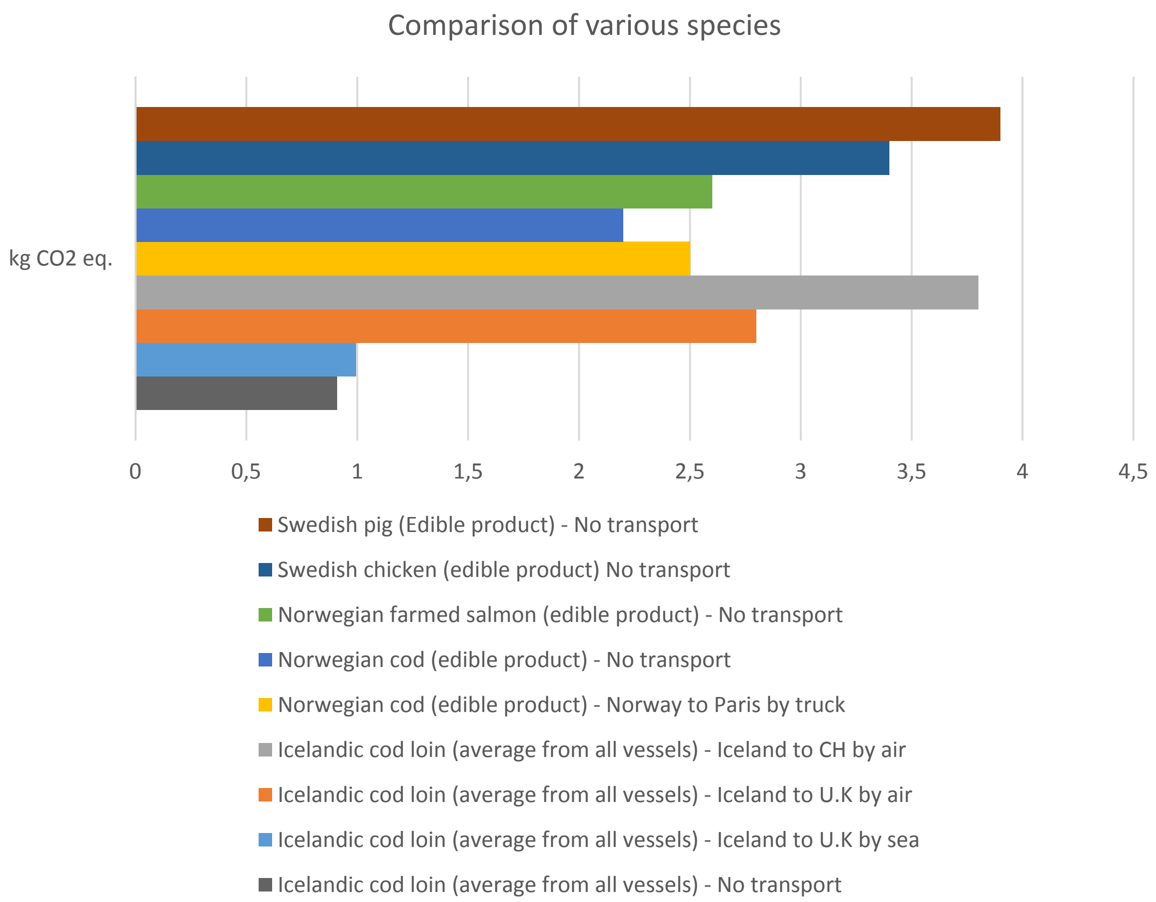

Figure 55. Comparison of carbon footprint from various studies. Swedish pig, Swedish chicken and Norwegian farmed salmon from YtrestØyl et al. (2010). Norwegian cod from Winther et al. (2009). Showed in kg CO_2/kg product.

Although Iceland seems to be able to deliver cod loins out of the ocean with reasonably low carbon footprint, the country's location in the middle of the Atlantic Ocean, far from mainland markets, means that all products have to travel relatively long distances. It can be seen that the Norwegian cod emits 2,2 kg CO_2 eq./ kg edible product, out of the processing house. By comparing the Icelandic cod with the Norwegian cod from Winther et al. (2009) and transport them from and to the same location, the Icelandic cod performs considerably better in terms of emitted CO_2 as seen in Figure 56. It should be noted that comparison with kg/edible product is risky, as opposed to kg/cod loin in this study. Edible product means the parts of the fish that are consumable when cut-offs and viscera are removed. Winther et al. (2009) use 62% edible yield of the Norwegian cod with the rest used in feed production. In a sensitivity analysis, Winther et al. (2009) change the edible yield of cod from 62% to 70% and gain 5,6% less CO_2 emitted. This underlines the importance of better utilisation.

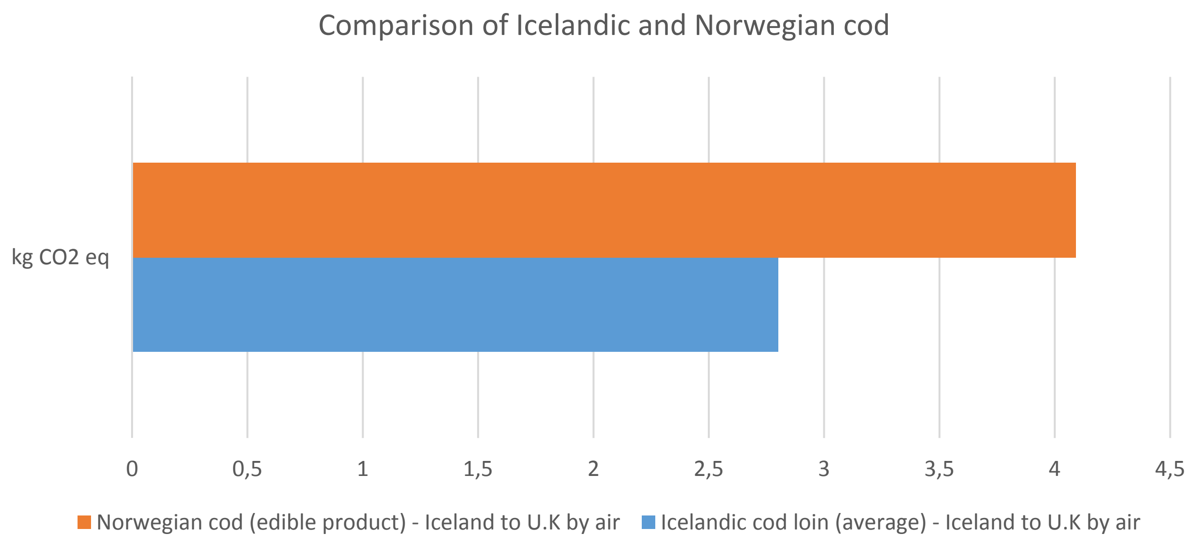

Figure 56. Comparison of 1 kg of Icelandic cod loin and Norwegian cod (edible product) from Winther et al. (2009) if transported from and to the same location. Showed in kg CO_2/kg product

Another similar study on high sea fish and salmon aquaculture was done by Buchspies et al. (2011) using 1 kg fillet at supermarket in Switzerland as functional unit and allocated by economic value. It was assumed that the cod was caught in Northeast Atlantic Ocean by trawl or gillnet vessels whereas mackerel and herring were caught by trawl nets only. The cod fillets are frozen, were packaged in plastic laminated cardboard boxes and transported by truck to Switzerland. The Mackerel and herring were canned. All fish was landed, processed and packed in Denmark while the salmon was raised in net-pen aquaculture in Norway.

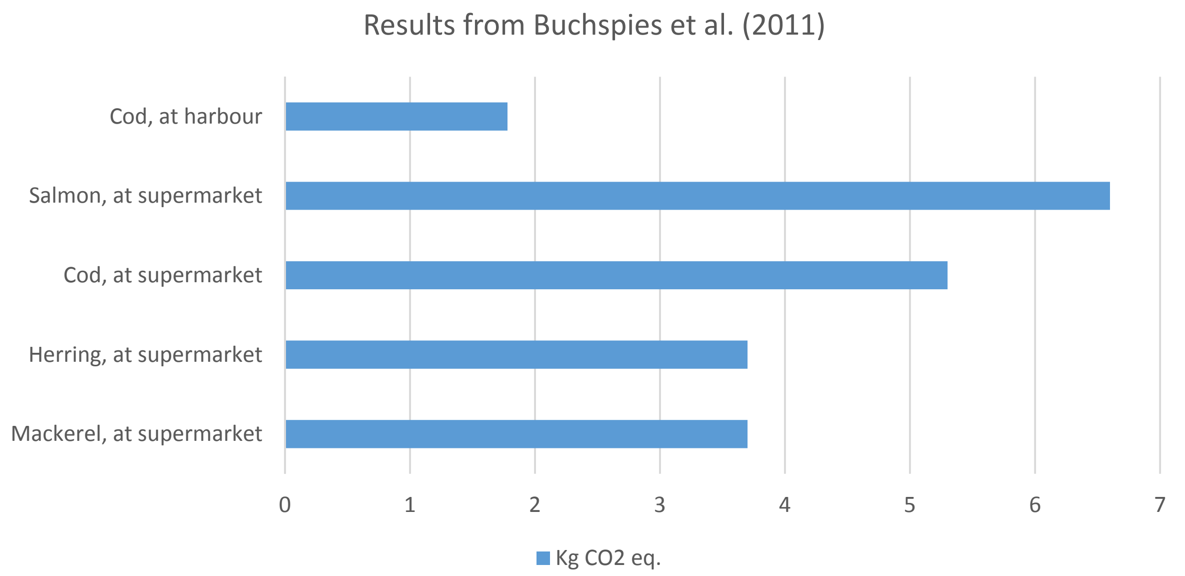

Figure 57. Results from Buchspies et al. (2011). Showed in kg CO_2/kg product

The results from Buchspies et al. (2011) show considerably higher carbon footprint than in the cases assessed in this study. They note that the aluminium cans that herring and mackerel are packed into cause more emissions than the plastic foil for other species. It should also be noted that the cod fillets are frozen and require refrigerated transportation.

A comparison with other types of food protein production was also shown in Buchspies et al. (2011), which showed that carbon footprint of veal, beef and lamb far exceeds those of the cod in that study. It also showed that pork and poultry have similar footprints as the cod. In Figure 58 the results from this study has been added to the comparison made by Buchspies et al. (2011).

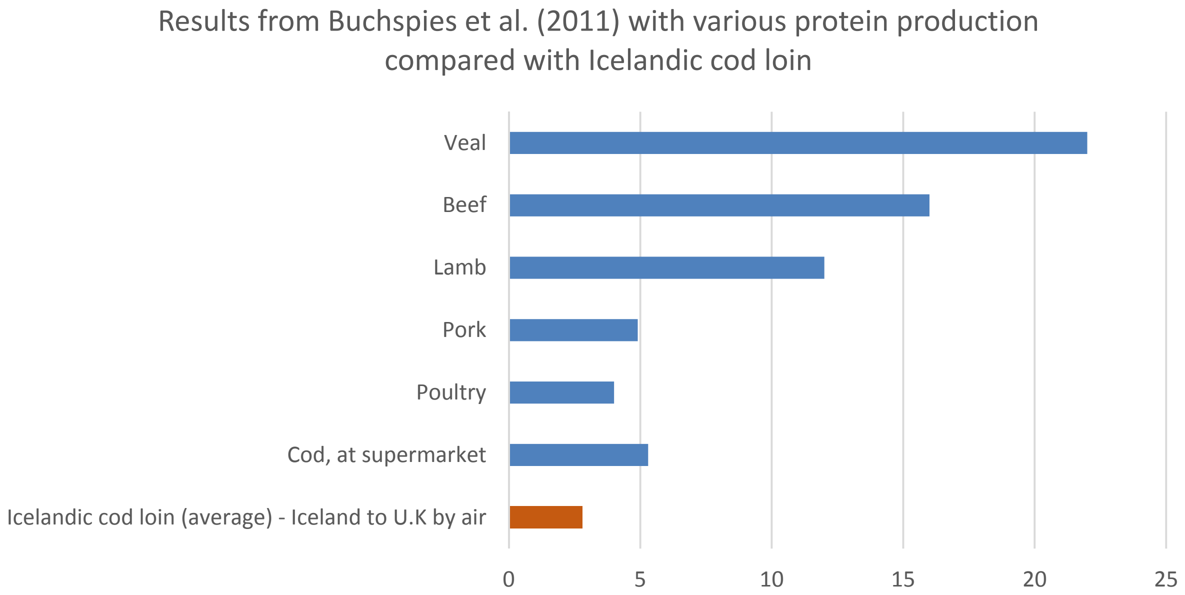

Figure 58. Results from Buchspies et al. (2011) with various protein production compared with Icelandic cod loin. Showed in kg CO_2/kg product

This demonstrates that fish protein in general releases far less greenhouse gas emissions than most meat products and that fresh Icelandic cod loins have relatively low carbon footprint compared to other animal proteins, even despite of being airfreighted from Iceland to the UK.

4 Conclusions and Discussions

The carbon footprint calculated for Icelandic cod loin, transported fresh to the U.K. or Switzerland by sea or air, fished by long-liners or trawlers, can be seen in Figure 59 with mean values divided between types of fishing gear. It is clear that fishing gear has considerable impact on carbon footprint values, but is overshadowed by the transport by air. Interestingly, but explainable, the transport by sea to the U.K emits even less CO_2 than the domestic transport. Minimizing the carbon footprint, and environmental impacts in general, associated with the provision of seafood can make a potentially important contribution to climate change control.

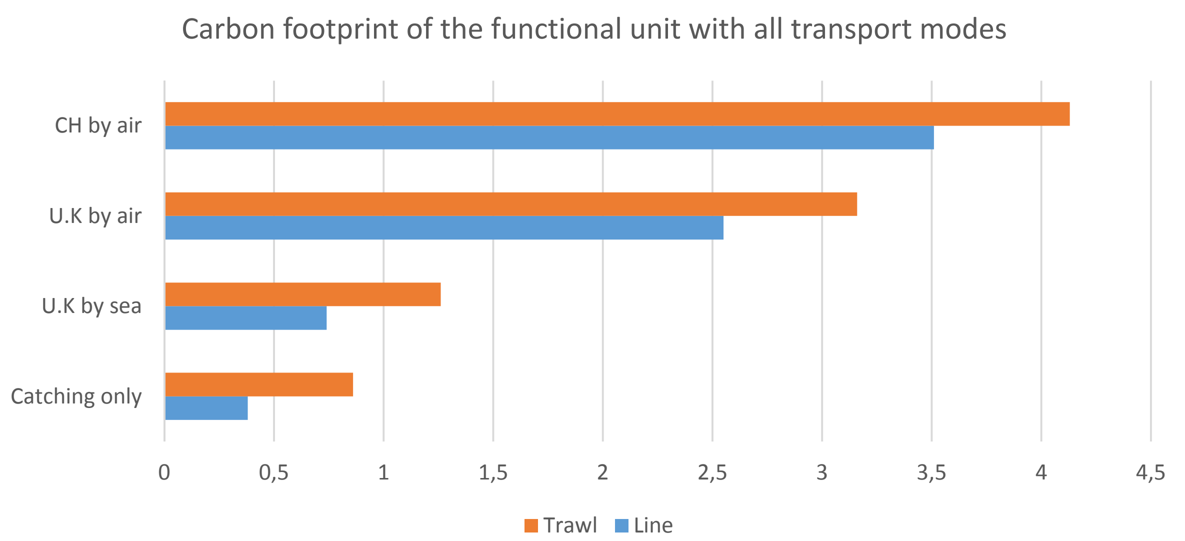

Figure 59. Carbon footprint of the functional unit with all transport modes. Mean values for liners and trawlers. Showed in kg CO_2/kg product

The variation in carbon footprint between the vessels assessed can be traced to a number of important factors, fishing gear as mentioned above and differences in fuel efficiency, ranging from 328 liters/ton down to 70 liters/ton in this study. Tyedmers (2004) reported a 500 liters/ton average for 29 North Atlantic fisheries 10 years ago, which indicates better fuel efficiency today and/or that a re-evaluation of those numbers is needed. Of course, many other factors affect the ratio between oil consumption and total catch such as distance travelled to fishing grounds, quota possession and composition, engine and ship type and health and management of fish stocks. No discrimination is done between companies or vessels in this study on how they are managed regarding general target species and difference in fishing ground location for example. All vessels except those of FISK seafood have close range fishing grounds near the westfjords, which could translate into longer travel times for FISK's trawlers. Because of how strong the cod stock around Iceland is, and how it is structured and managed, it is considered relatively easy to catch. That is however not the case for some of the other species the vessels in this study are targeting. Since the data from each vessel spans over a whole year it is not necessarily representative for cod fishing only. Therefore it can vary how much time each vessel spends on following up on other species, since cod is not the only targeted species of the vessels, at least not all the time.

The results of the study show and confirm that transporting via air has huge environmental impacts compared to sea and road transport. The remarkable emissions related to air freighting of cod is due to the highly resource demanding mode of air transport. Sea freight is a very fuel efficient transport mode compared to both air freight and even truck freight due to the fact that trucks consume more fuel oil per kg/km than a sea freighter, and that fuel consumption and CO_2 emissions are correlated. For example, recommended average emission factors for transport is as follows: Deep-sea container – 8 gCO_2/ton-km, Road transport – 62gCO_2/ton-km (Cefic, 2011). It is however understandable up to a point, that buyers and consumers choose to transport fresh and sometimes frozen products via air freight due to much shorter travel times. However, in a recent study by Margeirsson et al. (2012) where the comparison of transport modes and packaging methods for fresh fish products was assessed, the results showed that by transporting fresh fish in a ship, the freshness of the fish holds for 11 days, compared to 9 days via air, due to better temperature control, but of course transporting via air takes considerably shorter time as mentioned before. The advantage in CO_2 output is clear however, and should make this an interesting option with updated technology and methods of storing and cooling.

Most of the environmental impacts from the processing phase came from the production of packaging material. Margeirsson et al. (2012) also showed that by using reusable containers to transport fish products, the overall carbon footprint could decrease dramatically. Reducing energy intensity could lower the carbon footprint to some extent but the Icelandic renewable energy plays a big role in limiting contributions to climate change.

4.1 Situation in Iceland

Fisheries have been the backbone of Iceland's prosperity for decades and the countries fishing sector and connected industries are considered world leaders in implementing innovative solutions in every stage of the value chain that improve utilisation, efficiency and quality. The natural resources around and in Iceland are generous, but their condition will degrade unless sustainable utilization is maintained. With that in mind, Iceland has become a model country for developing a quota system for the fishing industry which ensures responsible and sustainable fishing and responsible fishing practices. The utilization of the catch in processing is among the highest known in the world. Iceland manages the fishing chain entirely by itself and has a complete control over how it is carried out. This has given Iceland a unique reputation in fish stock management in addition to the relatively clean and cold North-Atlantic Ocean.

Since global warming, like its name indicates, is global, Iceland's fishery fleet and its corresponding value chain is not excluded from contributing to the problem. Although innovation, technology and global awakening has led to improvements within the fishery industry regarding greenhouse gas emissions, necessary steps still need to be taken, including efficient transition from fossil fuels. Icelandic fisheries seem to deliver seafood with relatively low carbon footprint when compared with similar studies. That fact should increase the industry's reputation even further.

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