THE SWEDISH INSTITUTE FOR FOOD AND BIOTECHNOLOGY

SIK report 746

Environmental Life Cycle Assessment of Norway lobster (*Nephrops norvegicus*) caught along the Swedish west coast by creels, conventional trawls and species-selective trawls.

A data report

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December 2006

ISBN 91-7290-247-7

Sammanfattning

Havskräftan (*Nephrops norvegicus*) är för närvarande den ekonomiskt sett enskilt viktigaste arten i fisket längs västkusten jämte räkan (*Pandalus borealis*). Kräfta fiskas huvudsakligen med bottentrålar (80% av landningar), men också med burar (20% av landningar, främst i Skagerrak). Föreliggande arbete gick ut på att kartlägga miljöpåverkan av konsumtion av 300gram kräftstjärtar med hjälp av metoden livscykelanalys (LCA). Förutom den ekonomiska betydelsen av detta fiske, var anledningen till valet av denna fallstudie tillgången på kartor över havsbotten i Kattegatt som gjorde det möjligt att använda en nyutvecklad metodik för att bedöma effekter på havsbottnar av fiske.

Produkten följdes från fisket över fiskauktion, till grossist, butik och konsument. Livscykeln slutade efter kommunal avloppsrening. I analysen inkluderades produktion av el, förpackningsmaterial, båtbottenfärg, is och fiskeredskap samt avfallshantering. Produktionen av fiskebåten och andra kapitalvaror (utrustning, byggnader, infrastruktur mm) uteslöts. Data samlades in genom en enkät som skickades ut till samtliga fiskare yrkesverksamma i kräftfisket längs västkusten, från Fiskeriverkets databaser, från diverse företag längs kedjan på land och slutligen från LCA-databaser (bakgrundsdata som t ex elproduktion och avfallsförbränning).

Ett delmål med denna studie var, pga uppdelningen på de två fiskemetoderna, att jämföra dessa ur miljösynpunkt. Resultaten blev tydliga. Burfisket ledde till mindre miljöpåverkan i samtliga kategorier trots att man använder över ett kg sill som agn per kg landad kräfta i burarna och sillfisket var inkluderat. Dieselåtgången för trålarna var mer än fyra gånger högre per kg landad kräfta (9.0 mot 2.2 l/kg kräfta). Runt 10% av bränsleförbrukningen i burfisket berodde på agnfisket. När det gäller påverkad bottenyta var skillnaden än större. Hela burfisket påverkade en lika stor bottenyta under ett helt år som en timmes trålning. I burfisket påverkades 1.8m^2/kg kräfta, i trålfisket trålades 33000 m^2 per kg kräfta. Runt 3000 m^2 lerbotten påverkas permanent per kg trålkräfta landad, motsvarande en ruta på 55m x 55m. Dessutom är den oönskade fångsten mindre. I burfisket dog mindre än 0.15 kg fisk per kg kräfta landad. I trålfisket dog 4.5 kg småkräftor och fisk per kg kräfta som landades (samt okänd mängd av ryggradslösa djur i bägge fisken).

Det som talar emot burfisket är risken för allvarliga olyckor och arbetsmiljöförhållandena, som är sämre på de mindre burbåtarna än på trålarna. Materialåtgången för burarna är väsentligt högre än för trålarna, räknat per kg kräfta landad, delvis pga att redskap eller nät ifrån burarna förloras i större utsträckning. Detta utgör också en miljörisk då redskapen kan fortsätta ”fiska” och döda marina djur. Lönsamheten är sämre i burfisket trots högre priser för produkten. Vissa tycker att burfiskad kräfta smakar agn. Den högre andelen rombärande honor i burfångsterna ger en ökad risk för rekryteringsöverfiske. För de flesta av dessa problem finns det dock relativt enkla tekniska och/eller strukturella lösningar.

Detta bekräftar resultat i tidigare studier av andra fisken: att det är stor skillnad mellan fiskemetoder vad gäller miljöpåverkan och att man kan åstadkomma stora förbättringar genom att gynna existerande eller påskynda utvecklingen av nya miljöanpassade fiskeredskap. Det är också viktigt att genomföra tekniska förbättringar inom varje fiske som gör det mindre resurskrävande. Förbättringsmöjligheter för respektive fiske diskuteras kort i slutet av rapporten. En vetenskaplig artikel kommer inom kort att publiceras baserad på denna studie där fokus ligger mer på analys och diskussion än på datarapportering.

Summary
Norway lobster (*Nephrops norvegicus*) is currently the economically most important species in Swedish fisheries in the Skagerrak and Kattegat, the easternmost parts of the North Sea besides shrimps (*Pandalus borealis*). It is fished mainly by demersal trawls (80% of landings), but also by creels (20% of landings, mainly in the Skagerrak). The present study aimed at assessing the environmental impact of consumption of 300 grams of Norway lobster tails by applying Life Cycle Assessment (LCA) methodology. An additional reason behind the choice of this case study (except the economical importance of the fishery) was the availability of marine habitat maps in the Kattegat, which made it possible to apply a recently developed methodology to assess the seafloor impact of demersal fishing activities.

The product was followed from the fishery over the seafood auction, to the wholesaler, retailer and consumer. The lifecycle was finished after municipal waste treatment. Production of electricity, packaging materials, anti-fouling agents, ice and fishing gear as well as waste treatment was included. Production of the fishing vessel and other capital goods (buildings, infrastructure, equipment etc.) were excluded. Data was gathered by sending out a questionnaire to all professional fishermen active in these fisheries, from the database at the National Board of Fisheries, from various companies involved in the life cycle on land and finally from LCA databases (for background data such as electricity production and waste treatment).

A partial goal, due to the occurrence of two different fishing methods, was to compare these with regard to environmental performance. The results were very clear. Creel fishing caused less environmental impact in all categories even though over one kg of herring is used as bait in the creels per kg of *Nephrops* landed and the herring fishery was included. Diesel consumption of the trawlers was more than four times as high as of the creel fishing vessels (9.0 and 2.2 l/kg of *Nephrops*, respectively). With regard to seafloor impact, the difference was even more pronounced: The entire west coast creel fishery affects the same seafloor area during one year as does one hour of trawling. In the creel fishery 1.8m^2/kg *Nephrops* was swept, in the trawl fishery around 33000 m^2/kg *Nephrops* was swept. An area of 3000 m^2 of muddy seafloor habitat is kept in a permanently disturbed condition due to each kg of trawled *Nephrops* landed, corresponding to a square of 55m x 55m. In addition, less than 0.15 kg of undersized fish were killed per kg of Norway lobster landed in the creel fishery, while 4.5 kg of undersized *Nephrops* and fish, were killed in the trawl fishery (as well as unknown amounts of evertebrates in both fisheries).

Negative aspects of creel fisheries include safety and working conditions onboard which are better on the trawlers, lower rentability despite higher prices and higher risk of ghost fishing and recruitment overfishing, the latter due to the higher proportion of berried females (carrying roe) in creel-fished compared with trawled landings. In addition, some people think that creel-fished lobsters taste like the bait. For most of these problems, however, technical and/or structural solutions exist.

Results confirm previous findings in studies of other fisheries: There is a huge difference in the environmental performance of different fishing methods and it is possible to achieve great improvements by supporting the use of existing and facilitating the development of new, environmentally efficient fishing gear. It is also important to implement technical improvements within each fishery. Improvement options are discussed briefly at the end of the report. A scientific article based on the findings in this study will soon be published where focus is more on analysis and discussion and less on data reporting.

Keywords: Life Cycle Assessment, creel, trawl, Norway lobster, *Nephrops*

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Remark: *Nephrops*, *Nephrops norvegicus*, lobster and N.L. are all used as synonyms to Norway lobster in this report.

1. INTRODUCTION

1.1 Seafood production

Seafood is produced either by capture fisheries or by aquaculture. Fisheries exploit wild resources with limited production, while aquaculture is more comparable to agricultural production in the sense that the type and amount of food produced can be controlled. Fishing is the only type of industrialized food production which is based on wild production. Fishery can be undertaken with various fishing methods that are suitable for different species, depths, types of seafloors and vessel sizes. Two main groups of gear are active and passive fishing gear. Active means that the gear is actively pulled forward by engine force, such as trawls and dredges. Passive means that the gear is set and left in the water to fish for a period after which it is hauled, e.g. gillnets, creels and long-lines.

Globally, seafood production is peaking at 133 Million tons per year (data in this section from SOFIA 2004). In 2002, two thirds of global seafood production originated in fishery and nearly one third in aquaculture. Seafood production from fisheries has, after reaching the highest level in history in 2001, stabilized at around 93 Million tons, while aquaculture is the fastest growing animal-based food producing sector. Around 30% of the global wild catches are not directly used for human consumption but reduced to fishmeal and fish oil which is used for industrial purposes, e.g. feed production for aqua- and agriculture. Seafood is healthy food and an increasingly important protein source in both developed and developing countries. At the same time, half of the worlds major marine stocks for which assessment information is available are fully exploited and 25% are over-exploited, significantly depleted or recovering from depletion. This implies that only around 25% of the stocks are under-utilised or moderately exploited. The trend is that the number of fully exploited species is relatively stable while the number of under-utilised and moderately exploited stocks is decreasing slightly at the same time as the number of over-exploited and depleted stocks is increasing slightly.

1.2 Environmental problems related to commercial fishing

The environmental effects of fishery include direct effects on the stocks and production of the target species. As fisheries normally cannot be targeted at a single species, stocks of by-catch species which are landed and sold, are also affected. Some species are caught, but later discarded, together with damaged, low-value or undersized specimens of commercial species. Other fishery effects include changes in biological, physical and chemical conditions on the seafloor due to the use of towed gear; toxic emissions of active substances from anti-fouling paints and emissions from combustion of diesel fuel. Some of the environmental aspects of fishery are introduced briefly below.

1.2.1 The target species, by-catch and discard

A fishery normally has one or several target species, which is the main purpose of the fishing activity. A number of by-catch species are generally also landed and sold. They are not the main driving force of the fisherman, but have a commercial value and are therefore regarded as by-products that should account for some of the environmental impact caused by the fishery. The extraction of a considerable part of the biomass of target and by-catch species affects the standing stock size, rate of production and age and size composition of the stock of these species. Fishing also has more indirect effects on the surrounding marine ecosystem (Steneck and Carlton 2001).

Discard is, in contrast, the part of the catch, which is unwanted and normally thrown overboard. Discards consist of both undersized and damaged specimens of the target species and species with a low commercial value (Alverson 1994). When quotas are limiting, commercial sizes of the target species may be discarded, a phenomenon called upgrading. The fisherman on such occasions wants to “save” quota for a later catch (Pascoe 2000). The discarded individuals do usually not survive the treatment of being caught, taken onboard and then thrown back into the sea and therefore this loss of resource has to be accounted for as an environmental impact. Globally this loss has been estimated around 27% of total catches (Alverson 1994), but it seems as if this ratio has decreased considerably during the last decade (Kelleher 2005). Discarding is a widely recognised resource management problem in fisheries. Seafood from capture fisheries is a limited resource, although renewable, since the limits for production of most of the commercially exploited species have been reached (SOFIA 2004) and we cannot control production in the way we can for other food types. The discard of under-sized, commercial species is therefore a waste of a limited resource since it could have been fished later, when it would have reached commercial size. Moreover, discarding can contribute to eutrophication especially in cases where the biomass discarded exceeds the biomass landed and discarding is done in eutrophied, coastal waters with limited water exchange. Such fisheries lead to a net increase in biological turnover by making dissolved and particulate nutrients available to the marine food web. This could accelerate ongoing eutrophication and oxygen-depletion processes, an aspect discussed later in this report.

1.2.2 The seafloor

Although internationally there are many experimental studies on the seafloor impact of active fishing gear, local or regional data on fishing intensity and biological effects of fishing disturbance are rarely available. Known biological effects of fishing include the direct impact of demersal gear in the trawl track, killing or injuring benthic organisms living in the upper layers of the sediment (Kaiser and de Groot 2000). Indirect mortality is caused by exposing burrowing organisms to predators at the sediment surface. Filtering organisms may not cope with the increased re-suspension of sediments following the passage of fishing gear, resulting in increased mortality. The re-suspension and turbation caused by the passing trawl can also increase nutrient flux from the sediment to the water column (Pilskaln et al. 1998). The nutrient increase could accelerate ongoing eutrophication and oxygen-depletion processes further. The effects of fishing depend both on the marine habitat type impacted and on the frequency of the fishing activity (Nilsson and Ziegler 2006).

1.3 Environmental Assessment of seafood

There is an increasing demand for environmental information about seafood production both from consumers, companies in the seafood sector and authorities managing fisheries and the marine environment. In recent years, methods for environmental assessment of the fishery-specific types of environmental impact have been developed, even if there is still work to do in this field. Environmental Assessment with a life cycle approach means that the highly different environmental aspects connected to seafood production throughout the life cycle (e.g. carbon dioxide emissions, discard and seafloor impact) are quantified and lined up together, not for comparison, but to give a picture as complete as possible of the overall environmental impact of a certain product. Emissions and resource use are then classified into environmental impact categories such as global warming, abiotic resource use and eutrophication. The method Life Cycle Assessment is standardised in ISO (ISO 2002).

1.4 Purpose

The goal of the present study was to quantify resource use and environmental impact caused by the production of Norway lobsters by creels and trawls. A secondary goal was to evaluate the environmental consequences of the introduction of a fishing regulation in 2004, the species-selective grid, in the trawl fishery. Norway lobster was chosen because it is the economically most important fisheries in the Kattegat and due to the availability of marine habitat maps from this area. Previous work led to a method to quantify the seafloor impact of active fishing gear (Nilsson and Ziegler 2006) and the choice of this case study made it possible to apply the method in a seafood LCA.

2. GOAL AND SCOPE

2.1 System boundaries

The product is followed from the production of supply materials such as fuel, electricity and packaging materials over the fishery, transportation, retailing and to the consumer, see Figures 1and 2. The life cycle is ended after municipal sewage treatment where the nutrients contained in the Norway lobsters are released back into the sea.

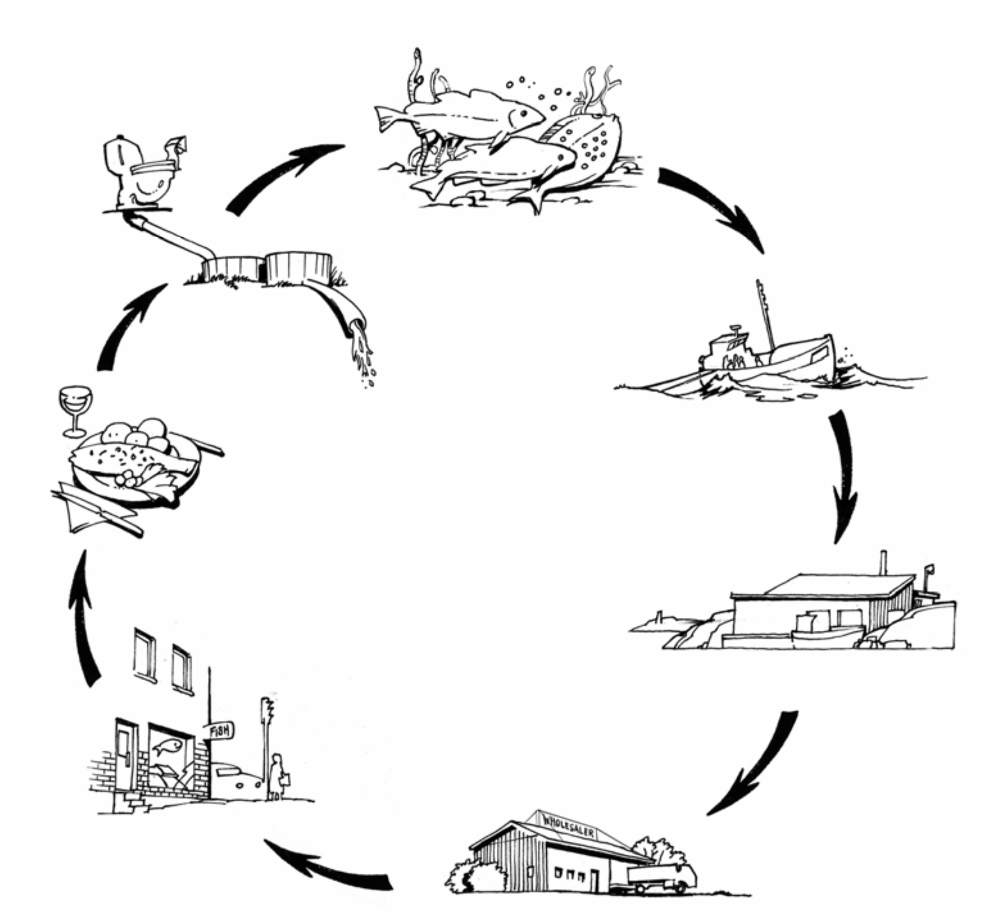
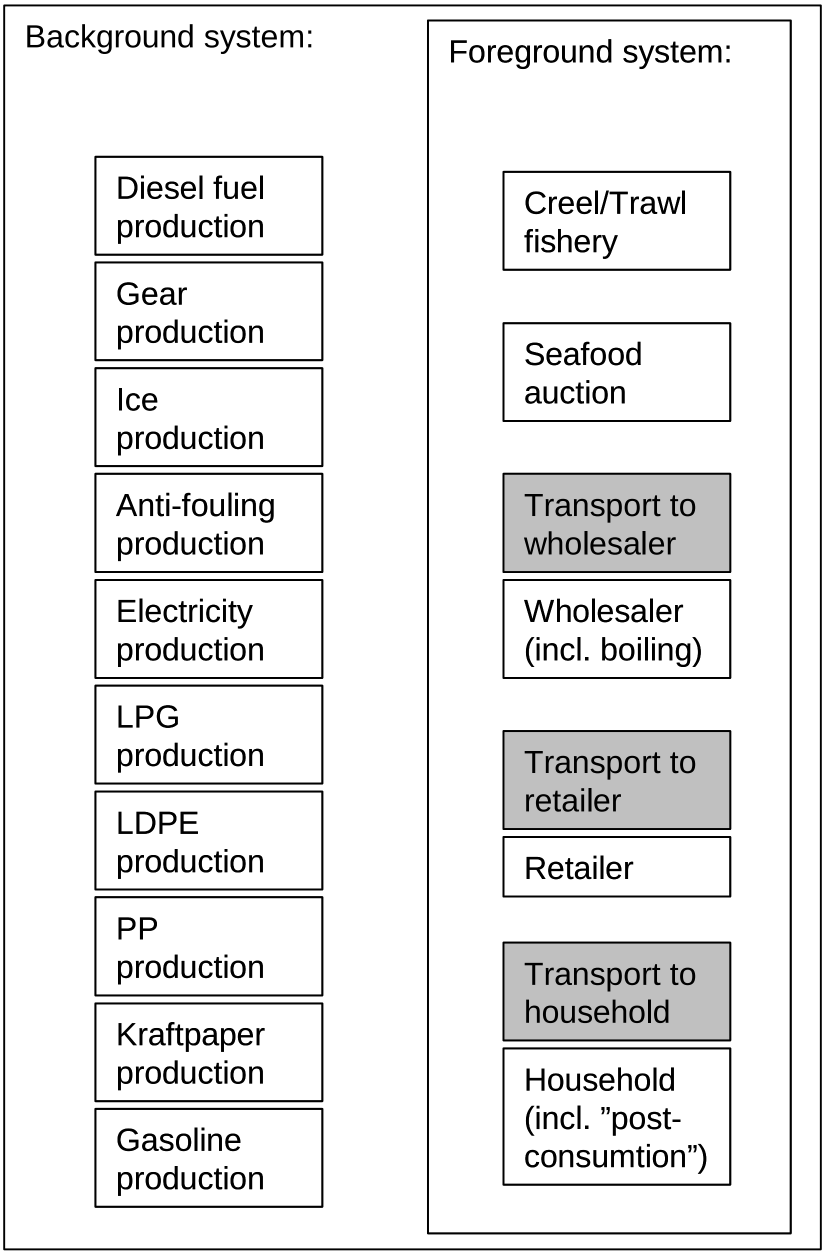


Fig. 1a) General life-cycle of wild-caught seafood products from the fish stock through the society, ending with municipal sewage treatment that leads the remaining nutrients in the product back to the sea (illustration by Jürgen Asp).



LPG= Liquified petroleum gas; LDPE= Low density Polyethylene; PP= Polypropylene

Fig. 2 Activities in the life cycle of boiled, fresh Norway lobsters

2.2 Functional unit

The functional unit was 300g of meat from average-sized Norway lobsters bought as fresh, boiled lobsters at a fish retailer in Gothenburg and consumed cold in a private household. Three different cases of fishery were included: creel fishery, conventional trawling and species-selective trawling. As the product exchange is 30%, the functional unit corresponds to one kilogram of Norway lobsters.

2.3 System description

2.3.1 The fishery

The Swedish *Nephrops* fishery takes place along the western coastline of the country in the easternmost parts of the North Sea, the Skagerrak and Kattegat. Swedish annual *Nephrops* landings have fluctuated around 1000 tonnes since the mid 1980's. In 2005, 1052 tonnes were landed. Around 100 trawlers (landing 80% of total *Nephrops* landings) are active in this fishery. The Swedish creel fishery for *Nephrops* started in the mid 1980's and contributed approximately by 10% to the total landings until the late 1990's. Between 1999 and 2005 the number of creel fishing vessels has increased with 50% to 110. In 2005, the creel fishing vessels landed around 20% of total landings, mainly from the northern part of the area, i.e. the Skagerrak. The minimum landing size is 40 mm carapace length and the stocks are managed as one (i.e. for the Skagerrak/Kattegat and both fishing methods). The exploitation level of the Skagerrak/Kattegat *Nephrops* stock is currently considered to be sustainable, but catches are not recommended to increase due to uncertainty about the stock status in relation to threshold values (Ask and Westerberg 2006). A typical *Nephrops* creel is shown in Fig. 3a. These are baited with salted herring to attract the target species. Trawls in this fishery are either single otter trawl like the one shown in Fig.3b or twin trawls, i.e. two trawls pulled in parallel. Since 2004, the use of a species-selective grid (i.e. trawls are equipped with a Nordmore type sorting grid with 35 mm bar distance, shown in Fig.3c) is mandatory on Swedish national waters. This legislation was introduced with the aim to significantly reduce fishing mortality of both juveniles and adults of local populations of demersal fish species like cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) and to protect habitats sensitive to trawling disturbance (Valentinsson, unpubl.). In 2005, 34% of Norway lobster catches were landed by trawls with sorting grid, 46% by conventional trawls and 20% by creels. The catch composition of the three fishing methods is shown in Figure 4.

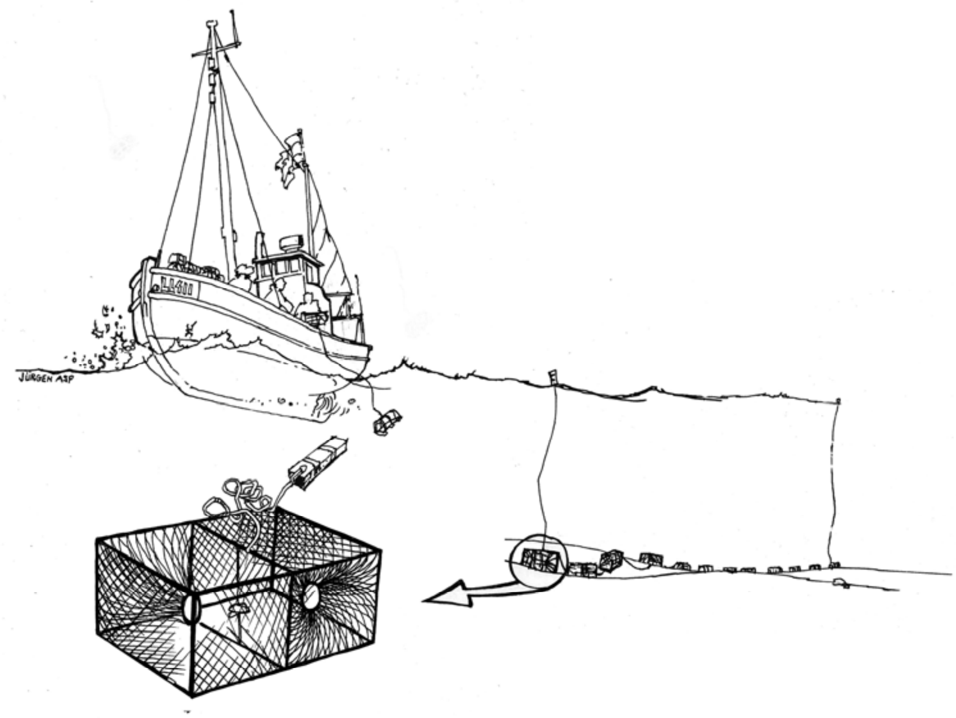


Fig. 3a) Creel

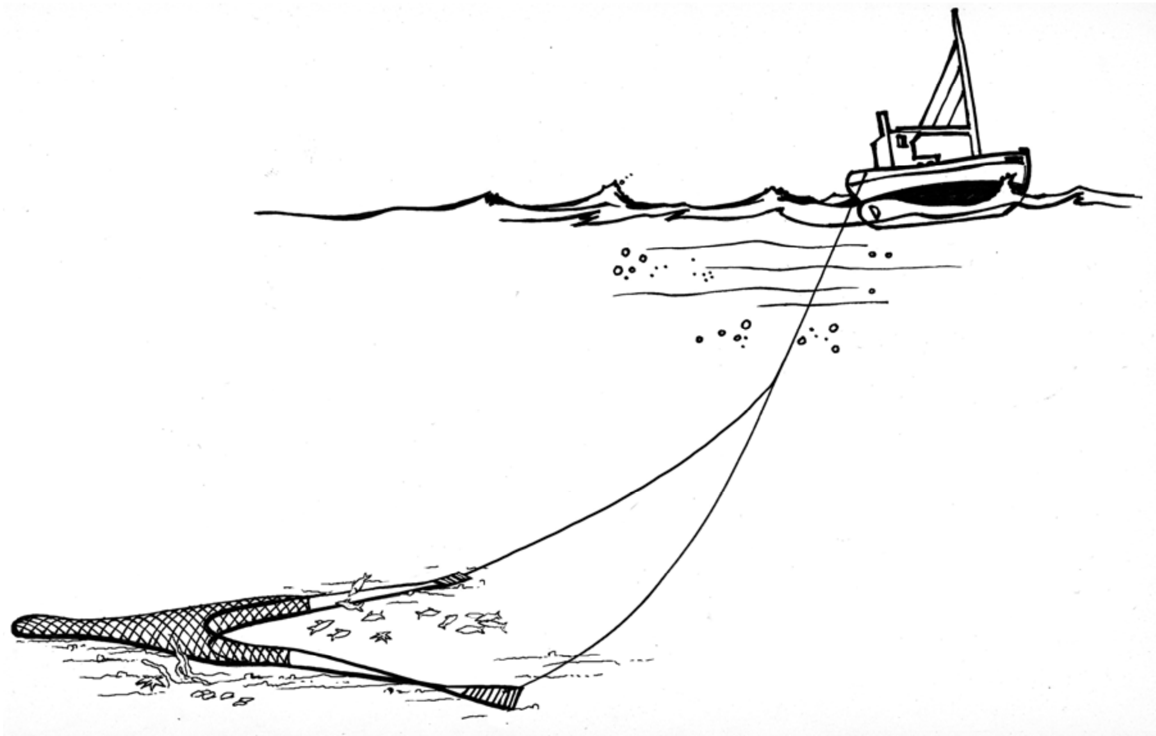


Fig. 3b) Conventional trawl

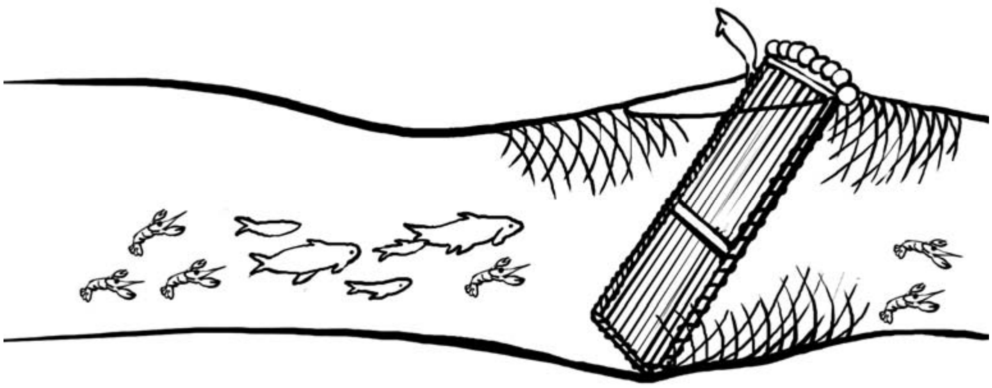


Fig. 3c) Selective trawl with sorting grid

Fig. 3 Common types of fishing gear employed in the Swedish west coast fisheries for Norway lobster (illustrations by Jürgen Asp).

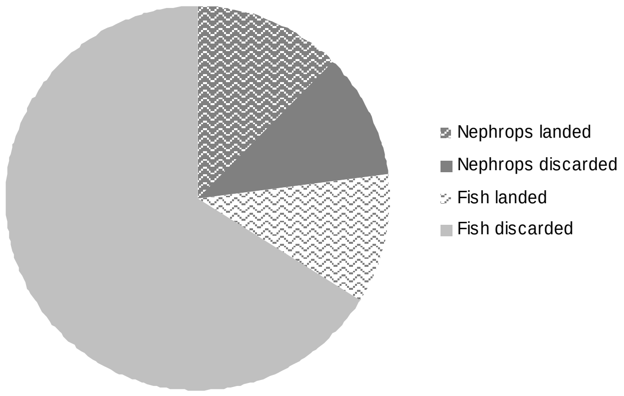


Fig. 4a)

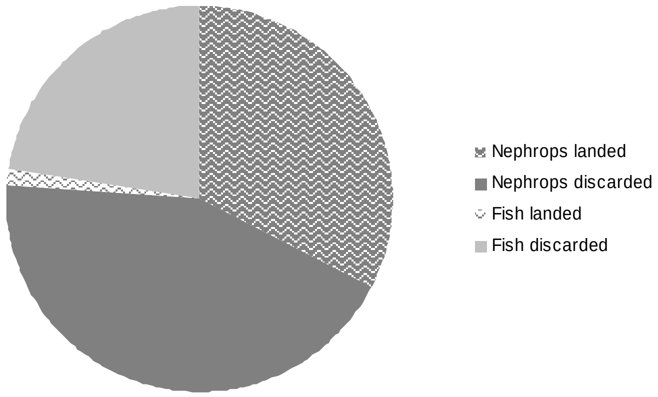


Fig. 4b)

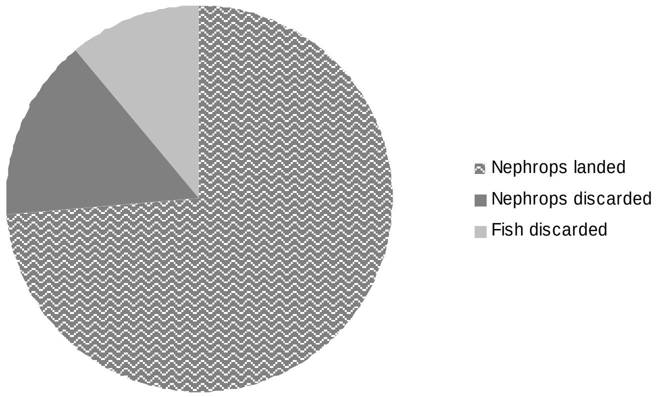


Fig. 4c)

Fig. 4 Catch composition of the three fishing methods: a) conventional *Nephrops* trawl (90 mm diamond mesh codend), b) selective *Nephrops* trawl (35 mm sorting grid and 70 mm square mesh codend) and c) *Nephrops* creels (please note that no estimations on natural and discard mortality are included here as is done in the calculation of discards per functional unit later, average for 2004-2005)

2.3.2 The life cycle on land

The major part of the Norway lobster caught in the west coast fisheries (i.e. in the Skagerrak and Kattegat) is sold as boiled, fresh lobsters directly to the end consumers by special fish retailers in Gothenburg. The lobsters consumed in other parts of the country, served in restaurants and processed to seafood products are normally imported. It is assumed that the life cycle after landing is identical for Norway lobsters caught by either fishing method.

3. METHODS

3.1 Data inventory methodology

3.1.1 Fishery

A questionnaire containing questions about fuel consumption, catches, gear types, gear material, anti-fouling and other chemical products as well as product quality was sent to the 78 fishermen who in the official fishery statistics had reported landings of more than 1000 kg of Norway lobster during two consecutive years, 2002 and 2003. This choice was done in order to target fishermen having Norway lobster fishery as their main occupation. The answers of 19 of them were used, 12 of them use creels and 7 trawls to catch Norway lobsters. The creel fishermen use between 300 and 700 creels on each fishing occasion and the main trawl types involved in the trawl fisheries were single (shown in Fig. 3b) or twin *Nephrops* trawls and combination trawls. Due to the small amount of available data, no attempt has been made to distinguish between the fuel consumption of different trawl types. Hence, the fuel consumption per catch landed was assumed to be identical for conventional and species-selective trawls. With regard to anti-fouling, only production and use was included (no packaging and transportation) and it was assumed that 2/3 of the copper in the paint was released to the marine environment. The Swedish Board of Fisheries provided data from their statistical database which is based on logbook data regarding all landings of Norway lobster in the Kattegat and Skagerrak during 2002-2005.

3.1.2 Seafloor use

The questionnaire mentioned above also contained questions about gear dimensions, that is width of the trawl opening and length of trawl boards and width and length of the creels. The trawl data provided a basis for the calculation of an index of area trawled per hour. The fishery data provided by the National Board of Fisheries showed the fishing effort by different gear types, in terms of hours fished. The gear index of each trawl type considered to target Norway lobster at least partially (that is lobster trawls with and without sorting grid, combination trawls and double trawls) was multiplied by the total effort of that gear type during a year (average of 2002-2003) and then divided by the total catches reported in the same data material in order to obtain a rough estimate on the average seafloor swept per landed catch in the trawl fishery. GIS analysis was then performed in order to assess the type of habitat impacted by this fishery and the biological impact of this activity. The total impact column was divided by 25 to obtain the proportion of 5 km x 5 km squares covered by each tow. Fishing positions (gear set position) in longitude and latitude were transformed to decimal degrees and the file was then saved in dbf IV format. It was imported into a project in the GIS software package ArcMap 9.0 (ESRI 2004) together with a map of marine habitats classified according to the European Nature Information System (EUNIS) (Anon. 2002), also used in Nilsson and Ziegler (2006). Fishing events with effort >12 h were excluded as well as positions on land (altogether representing around 3% of the data). The Neighbourhood statistics function in the ArcMap extension Spatial Analyst was then used to analyse intensity in 5 km x 5 km squares, both for the entire area and for each marine habitat type occuring in the area. The total number of squares in the whole area as well as in each habitat were available from previous work (Nilsson and Ziegler 2006). The analysis lead to estimates on proportions of area affected by fishing (for each habitat and for the entire area) and number of squares affected 0, 0-1, 1-2, 2-4, 4-6, 6-10, 10-12 and 12-18 times per year, respectively, and these fishing intensities were then evaluated in relation to MarLIN, a database on marine habitat sensitivity (Anon. 2004).

For the creel fishery, the average area of a creel was determined from the questionnaire as was the average number of creels used at one occasion. These figures were multiplied with each other and then multiplied by the number of efforts that occurred in the area (Skagerrak and Kattegat) during a year (average of 2002-2003) and divided by the total Norway lobster catch in order to obtain a number on the average seafloor use per landed catch in the creel fishery.

3.1.3 Discards

Data on discards in conventional *Nephrops* trawls was provided from programmes sampling commercial fishing vessels in terms of kg of undersized *Nephrops* and fish discarded per kg landed for the gear types and hauls targeting *Nephrops* (Y. Walther, pers.comm.). The main species discarded are described as are the biological and environmental consequences of this activity. Discard data for the species-selective trawl were gathered from the first evaluation of the regulation introduced in 2004 (Valentinsson, unpubl.). These data were gathered within the same onboard observer programme, sampling commercial vessels using both conventional and selective trawls in 2004 and 2005.

3.1.4 Seafood auction

After landing, the lobsters are traded at a seafood auction, mainly the one in Gothenburg. During a visit there, data was collected on the amount of lobsters, shrimps and crabs that pass the shellfish hall of the auction during a year as well as the annual electricity consumption. Cooling agents have not been refilled during the last couple of years so it was assumed that there was no consumption or emissions of cooling agents.

Trucks transporting seafood within the auction, cleaning of the hall and cleaning of the fish boxes used to land seafood and transport it up until the wholesaler was excluded due to difficulties in obtaining data related to the functional unit in combination with an assumption of relatively low importance of these activities.

3.1.5 Retailer and wholesaler

The retailer was a fish counter in a big supermarket with a high-quality profile located in the city center. The retailer was asked e.g. where and how often they buy their lobsters, how long they store them and how, which packaging materials they use and amounts typically sold to the consumer. The companies supplying equipment and packaging materials were contacted afterwards and data was collected for their respective parts of the life cycle.

The retailer buys his lobsters from a wholesaler who boils and packages the lobsters for him. The lobster-related activities of the wholesaler, boiling, packaging and storing, were therefore included in the data inventory. Also in this phase, manufacturers of equipment and packaging materials were contacted later to gather specific data on resource use. Waste treatment of packaging material and brine introduced at the wholesaler is included in the retail phase (where they leave the system). Only the freshwater used directly for the product (for cooking and for the brine) was included, not water used for cleaning. Cleaning agents and electricity for light and heating of building were also excluded due to difficulties in obtaining data in combination with an assumption of relatively low importance of these activities.

3.1.6 Transports

The wholesaler provided information on the transportation mode and distance to and from their company. Data on resource use and emissions caused by the different transports were taken from databases (see section 3.2 below) and added to the life cycle phase following the transport, i.e. the transport *to* the wholesaler was included in the wholesalers' activities, while the transport *from* the wholesaler was added to the retailer. The final transport from the retailer to the consumer (included in consumer phase) was assumed to be done by car and allocated completely to the lobsters as a "worst case" (see section 3.1.8 for arguments for this approach).

3.1.7 Consumer and sewage treatment

As the lobsters were already boiled and the most common way to eat them is just as they are the same day they were bought, no storage or preparation at home was assumed. Dishwashing was excluded as it was assumed to have low importance. Figures on product exchange were found in literature (Thrane 2004 and Anon. 1986) and compared with own experiments. Information on nitrogen content of Norway lobster was gathered from food tables (Anon. 1986). The nitrogen in the lobster meat was assumed to be released to the sewage system and being treated in a municipal sewage treatment plant for which energy consumption was included. The packaging materials appearing at the retailer are here leaving the system going to municipal waste incineration, together with the lobster shells.

3.1.8 Allocation strategies

In the fishery, allocation to the different by-catch species was done on the basis of their economical value (annual average values were used), as it has been shown previously that economical allocation is preferable over e.g. mass allocation in mixed fisheries where the landed species have great differences in economical value (Ziegler and Hansson 2003). System expansion, the method to handle co-products recommended by ISO, was considered not being feasible as there are no fisheries landing each one of the by-catch species separately. Moreover, system expansion would include a number of additional assumptions about what type of production the by-product replaces, which would make the results less transparent. The economical allocation is easier to look through for the reader. In storage and transports, volume or mass allocation is sometimes considered being the most appropriate choice (Ziegler et al. 2003; Thrane 2004; Ayer et al. unpubl.). In this case, however, storage was not limited by mass or volume neither at the auction, wholesaler or retailer why economical allocation was chosen in these phases, too. Rather, storage capacity was much greater than what was actually used. For transports, all the impact was attributed to the crayfish (no transportation of other goods was assumed) as a “worst case” both due to lack of information on the detailed logistics around Norway lobster transportation and due to an interest in seeing of this “worst” case would contribute significantly to the overall environmental impact.

3.2 LCA software and Impact assessment methodology

The software used for the LCA modelling was SimaPro Analyst 6.0.4. Database data used were taken from the databases Ecoinvent 1.01 (transports, electricity, fuel, paper, water and nylon production), Franklin (liquified petroleum gas) and ETH-ESU 96 (production of crude iron, salt, polyethylene and polypropylene) as was the characterisation method used for Impact Assessment (CML 2 baseline 2000 version 2.03). Environmental impact categories included in the study were: Global Warming (100 years), Acidification, Eutrophication, Photochemical Oxidation, Ozone Layer Depletion, Abiotic Resource Depletion, Human toxicity, Terrestrial toxicity, Freshwater toxicity and Marine toxicity. Biotic resource use, discards and seafloor use are categories of environmental impact that were quantified but not characterised, due to lack of characterisation methodology, they are though discussed qualitatively.

4. RESULTS

4.1 Inventory results

4.1.1 Fishery

The result of the questionnaire with regard to fuel consumption is shown in Figure 5. It is evident that trawling, especially conventional trawling, requires more fuel than does creel-fishing

Landed by-catch represented 41% of economical value in conventional trawling, 7% in selective trawling and 1% in the creel fishery. In creel fisheries 2.2 l diesel were burnt per kg of Norway lobster landed. In the conventional trawl fishery, 9.0 l diesel were burnt per kg of Norway lobster landed and in the trawl fishery with selective trawls, 4.3 l of diesel were burnt per kg of Norway lobster landed (recall that the same fuel consumption per kg of landed catch was assumed for conventional and selective trawling, the difference is hence only due to the cleaner catch composition). Cooling agents were not regularly refilled why it was assumed that consumption and emissions were negligible.

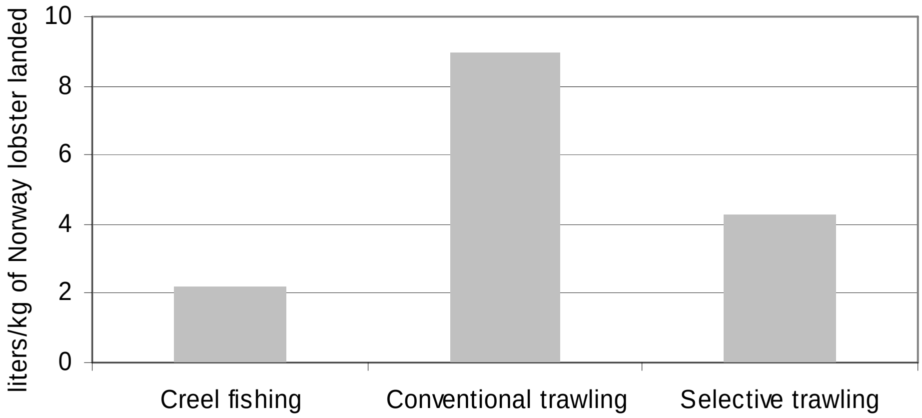


Fig. 5 Fuel consumption results for the three gear types

An additional aspect of the creel fishery is the use of bait. The bait used is salted herring (25 kg salt added to 125 kg of herring) and the amounts used were 1.1 kg of salted herring per kg of lobsters landed. The herring is often caught by the fishermen themselves or bought from pelagic trawlers. Data on fuel consumption and some emissions in herring fishery were found in Thrane (2004) and these data were used. Since the engine load of pelagic trawlers resembles the engine load of demersal trawlers (Meltzer and Bjørkum 1991), fuel combustion emission data used in the herring fishery *per g of fuel burnt* were the same as in the Norway lobster trawl fishery.

Table 1. Resource use and emissions per 100kg of mixed catch landed. The data for emissions to air were calculated from emission factors from Ziegler and Hansson (2003). All other data in the table are from the questionnaires.

Fishing method	Diesel	Ice	Anti-fouling	Lubricants etc.	Gear nylon	Gear metal	Bait	HC	NO_x	SO_x	CO	CO_2
	(kg)	(kg)	(g)	(kg)	(kg)	(kg)	(kg)	(g)	(kg)	(g)	(g)	(kg)
Trawl	341	318	218	1.5	0.050	0.085 (iron)	0	338	12	239	590	1080
Creel	162	57	145	2.0	2.4	9.4 (steel)	103	175	5.5	113	206	514

4.1.2 Seafood auction

At the Gothenburg seafood auction, there are two big halls, on of which is used to trade fish and the other, smaller one, to trade crayfish, i.e. shrimps, *(Pandalus borealis),* Norway lobsters *(Nephrops norvegicus)* and common crabs *(Cancer pagurus)*. During 2003, 597 tons of Norway lobster, 633 tons of shrimps and 84 tons of crabs passed the auction. In terms of economic value, Norway lobster represented 64% of the seafood value in the smaller auction hall. This hall holds a temperature of 2ºC, the fish hall holds 4-5ºC. When the seafood arrives in the evening or during the night, everything is first stored in the colder hall, but before the auction starts, the fish is moved to the bigger hall. As the colder temperature is actually not needed for the fish, this use is disregarded in the allocation of cooling energy. Use of freshwater, cleaning agents and trucks (for moving seafood from lorries to the auction hall) and cleaning of the fish boxes was excluded from the analysis due to lack of data and presumed low importance.

3600kg of crayfish are hence passing the auction every day, being cooled from about 10ºC to 2ºC. The cooling agent is NH_3 and it was not refilled during the period.
Total energy use of the crayfish hall is 160.9 kWh/day
160.9 kWh/day * 0.64 (proportion of economic value of Norway lobsters) = 102.99kWh/day due to Norway lobster
597000kg/year represents an average of 1636kg/day (hall is cooled 365 days/year)
(102.99kWh/day)/(1636kg/day)= 0.063 kWh/kg of Norway lobster = **0.22 MJ/kg of Norway lobster** (using 3.61MJ/kWh).

4.1.3 Wholesaler

Cooking of brine and lobsters

At the wholesaler, the lobsters are boiled, cooled and packaged. Hot water (67ºC) is taken from a hot water boiler (300l, Metrotherm AB) which requires 17kWh for heating a full boiler tank. This figure corresponds to 0.057 kWh/l hot water or 0.20 MJ/l of hot water.

First the brine is cooked and cooled using a LPG-burner (Liquified Petroleum Gas). According to the manufacturer, Gamo gasol AB, the burner uses 4 kg of LPG per hour under maximum use. 100l of hot water is brought to the boiling point together with certain amounts of salt and dill (dill was though excluded from the study due to lack of data), a process taking around 20 min. Thereafter the gas is lowered (burning 3kg/h) and the brine is cooked for about five minutes, then left to cool to room temperature in air and finally put in a cool storage room until used, the day after.

LPG contains 46.2 MJ/kg
20 minutes at 4kg/h and 5 minutes at 3 kg/h makes 1.58 kg LPG used per 100l of brine, which corresponds to 0.67 MJ/l of brine. Including the 0.20 MJ/l used for heating the water to 67ºC, gives a result of 0.87 MJ/l of brine produced.

The following day the lobsters are boiled in the following way. 50l of hot water are brought to boil together with salt and dill, taking around 10 minutes. The the lobsters are added, around 20 kg at a time. When they are boiling, the gas is lowered (as above) and the lobsters are boiled for around five minutes

10 minutes at 4 kg/h and an additional five minutes to bring the lobsters to boil again and then five minutes boiling at lower gas (3kg/h) gives 1.25 kg of LPG

Divided by 20 kg of lobsters this gives 0.0625 kg of LPG per kg of lobster or 2.89 MJ/kg lobster. Adding the heating of the water (10.2 MJ/50l of water divided by 20 kg of lobsters: 0.51MJ/kg of lobster) gives a result of 3.40 MJ/kg of boiled lobster (without brine).

Disposable buckets made of 750g of Polypropylene are filled with 8 kg of lobsters and then around 10l of brine are added, that is 1.25l of brine is used per kg of lobster.
0.87MJ/l brine *1.25l brine= 1.09MJ

Boiling at the wholesaler hence takes (3.40+1.09)= 4.49 MJ/kg lobster in brine.
Electricity: 0.75 MJ/kg Norway lobster in brine
LPG: 0.082 kg/kg Norway lobster in brine

Cold storage (at wholesaler)
Total mass of crayfish being stored in the two cold storage rooms used for crayfish during a year is a total of 23400 kg and the three species stored are Norway lobsters (20000kg), common crabs (700 kg *Cancer pagurus*) and lobsters (2700kg *Homarus gammarus*). Norway lobster represent 77% of the economic value of crayfish. Assuming only the Norway lobsters are put in brine after cooking, loading in the cold storage is 23400 kg crayfish/year (64.1 kg/day) and 25000l brine/year (68.5l/day) which gives a total of around 133kg/day being stored in the crayfish cold storage rooms. This amount of goods is assumed to be cooled from 20ºC to 2ºC in 4 hours.

The cooling agent used is R134a, but it is not refilled at all, why it is assumed there is no consumption and no emissions of R134a. The room is only running 16 h/day, since the machinery is actually larger than necessary.
(2.27kW*16h+0.7kW*4h)=39.1 kWh/day
39.1kWh/day*0.77 (=proportion of economic value of Norway lobster) = 30.1kWh/day due to Norway lobsters.
20000kg/year represents on average 54.8 kg/day (room is cooled 365 days/year)
(30.1kWh/day)/(54.8kg/day)= 0.55 kWh/kg of Norway lobster **= 1.98 MJ/kg of Norway lobster**

Total energy consumption at the wholesaler is hence 4.49 (boiling) +1.98 (cooling of product) MJ/kg= 6.47 MJ/kg

4.1.4 Retailer
The seafood counter handles (buys and sells) around 5500 kg of Norway lobster per year, corresponding to around 6-7% of the economic value of their sales and 20 kg per day. Around 10% in weight are creel-fished lobsters, an increasingly popular product mainly due to its greater size and higher quality. Lobsters are delivered almost every morning in the disposable buckets from the wholesaler which are put in cold storage. During the day they are taken out and put in a box (20*25 cm) in the cooled fish counter (in brine). The average effect of this specific counter (according to the installer, Kema Storköksförsäljning AB) is 0.4kW.

The energy consumption for product exposure at the retailer is hence 0.4kW*24h*0.065/20 = 0.0312kWh/kg or **0.11 MJ/kg**.

Cold storage
According to the company providing service to the cold storage rooms of the supermarket, Totalteknik AB, the room requires 13.7 kWh/day when loaded with around 50 kg of lobsters and brine holding around 10ºC, cooling the products to around 0ºC in four hours. The cooling aggregate is running 18 h per day to hold a temperature of 0ºC.

The energy consumption is 13.7kWh/day. Hence the energy consumption of the storage room is 13.7/20 kWh/kg= 0.685 kWh/kg if the room was only cooled for the lobsters. As the lobsters represent 6.5% of the economic value of sales in the seafood counter, economical allocation gives an energy consumption of 0.685kWh*0.065= 0.044kWh/kg or **0.16MJ/kg.**

The total energy consumption in the seafood counter is hence, 0.16+0.11MJ/kg= **0.27MJ/kg of lobsters.**

The cooling agent here is R404a which has not been refilled since the equipment was installed five years ago why no consumption or emissions have been accounted for.

Waste
The polypropylene (PP) bucket as well as the brine are leaving the system here. PP goes to municipal waste incineration and the brine to municipal wastewater treatment.

Packaging materials
A typical amount bought by the consumer is 1kg of lobster which is packed in a 1.81g LDPE-bag which in turn is wrapped in one sheet of brown, strong paper sealed with a label. When paying, the consumer packs this little parcel in a common plastic or paper bag. In order to evaluate the importance of these data in relation to the other life-cycle phases, a 2g LDPE bag, two sheets of brown paper and a 23g LDPE bag was included as packaging materials as a "worst case".

4.1.5 Transports
Transport from the seafood auction to the wholesaler: The transport distance was 9 km and it was first doubled as a "worst case", assuming no goods are replacing the lobsters on the way back and then multiplied by 1.1 to compensate for the 10% higher fuel consumption due to the cooling during transportation (also a "worst case", see Ziegler et al., 2003).

Transport from the wholesaler to the retailer: The transport distance was around 13 km which was likewise doubled and then multiplied by the factor 1.1 for cooling.

Transport from the retailer to the consumer: This transport was assumed to be done by car and on average to be 5 km one way (which was a guess). Due to the high value of lobsters in relation to other food items, this transport activity was, again as a "worst case", entirely allocated to the lobsters as transportation efficiency was assumed to be of minor importance in this case.

Data for the different transport types (passenger car and delivery van) were found in the Ecoinvent database (see section 3.2).

4.1.6 Consumer
Literature showed that 100g of edible Norway lobster tails contains 2.35 g nitrogen (Anon. 1986).The product exchange from whole lobster to edible tail is 30% (Anon. 1986, Thrane 2004a). In our own experiments the product exchange was somewhat higher, between 37-43%. The paper and plastic packaging materials introduced at the retailer are leaving the system at this point going to municipal waste incineration as are the non-edible parts (shells) of the lobsters hence representing around 70% in weight. Neither storage nor preparation and dish-washing was included as the storage time is minimal, the lobsters are normally eaten cold and dish-washing was assumed to have a negligible impact.

4.1.7 Municipal sewage treatment
It was assumed that the nitrogen contained in the product was leaving the household as wastewater for treatment in a municipal sewage treatment plant. Energy use for sewage treatment was taken from literature (Dalemo 1996)
For aeration 18MJ/kg nitrogen reduced are required, representing 45% of the total energy consumption of the sewage treatment plant, hence the total energy consumption is 40MJ/kg nitrogen reduced. Only energy consumption and nutrient emissions were included in this phase.

4.1.8 Overall uncharacterised life cycle results

Seafloor use

The seafloor area swept by conventional *Nephrops* trawls was calculated to be around 15000m^2 per kg of catch. After economical allocation (59% of the economical value of the catch was represented by *Nephrops*) and consideration that only 27% of the catch (in weight) was Norway lobster, the result was that 33000 m^2 were swept per kg of *Nephrops* landed (corresponding to a square of 182m x 182 m).

Results of the GIS analysis of high resolution fishing effort data from the Swedish Norway lobster fishery show that 29% of the total Kattegat area was affected by it in 2003. In the natural habitat of Norway lobsters, muddy seafloor areas, 86% of the area was affected by the fishery. Other habitats affected were sandy habitats (58% affected), Combination sediments (59% affected) and deep rocky habitats (100% affected). The latter is in part due to the small and patchy area of this habitat in relation to the size of the analysed squares (which was necessary due to the resolution of the trawl effort data), may therefore be an overestimation and should not be overinterpreted. Nevertheless, the borders between muddy and rocky areas are known to be good fishing grounds both for Norway lobsters and for some important fish by-catch species. With regard to intensity, it was likewise highest in muddy areas. The average number of times swept was 2.5 ± 2.9 times per year. A considerable part (36%) was swept more than twice per year and 15% was swept more than four times per year. In all other habitats, including the deep rocky ones, disturbance intensity was low, almost the entire remaining area was affected less than twice per year by these trawlers. In Nilsson and Ziegler (2006) a methodology for spatial analysis of demersal fishing effort data was developed. The biological impact of the found fishing intensities was evaluated using a British database (MarLIN) containing information on sensitivity and recoverability of marine species and habitats (Anon. 2004). The recoverability of muddy habitats from fishing disturbance is classified as high, i.e. recovering completely in six months to five years after a (single) fishing event. This would indicate than any muddy area which is being affected more often than twice per year remains in a disturbed condition which in this case corresponded to 36% of the habitat (or 1242 km^2). Hence, 1242 km^2 are kept in a permanently altered condition due to conventional *Nephrops* trawling landing 246 tons of Norway lobster, meaning that about 3000 m^2 per kg of Norway lobster landed (corresponding to a square of 55m x 55m) are permanently disturbed with the 2003 level and distribution of fishing effort[1].

The area impacted by the creels was much lower. The entire west coast creel fishery (landing 20 % of total lobster catches) affected a similar amount of seafloor area as did one hour of trawling. Per kg of catch (99% of the economical catch value is represented by Norway lobsters) the seafloor affected by creels was calculated to be 1.8 m^2.

The different catch composition in the catches of the species-selective trawl led to highly different results in all categories (as described for energy use), including seafloor use. Using the same figure for seafloor swept per kilogram of catch landed as for the conventional trawl, but the different catch composition of the selective trawl (98% of the economical catch value was represented by Norway lobsters, 93% in weight) gives a seafloor area swept per kilogram of Norway lobster trawled by selective trawls of 15600 m^2.

Discards

The amount of discard killed of all species in the conventional trawl fishery was calculated to be 4.5 kg per kg of *Nephrops* landed of which 0.4 kg is undersized *Nephrops* and 4.1 kg is undersized fish. Natural mortality of Norway lobsters (25%) and fish (20%) was accounted for as well as different discard mortality (Norway lobsters 75%, fish 100%). Main species discarded during conventional trawling were cod (*Gadus morhua*), flounder (*Platichtys flesus*), *Nephrops*, dab (*Limanda limanda*), whiting (*Merlangius merlangus*), plaice (*Pleuronectes platessa*), long rough dab (*Hippoglossoides platessoides*), edible crab (*Cancer pagurus*), gurnard (*Eutriglia gurnardus*) and hake (*Merluccius merluccius*).

[1] allocating the seafloor impact based on the economical value of catch and by-catch as previously

The species-selective trawl lead to considerably lower discards and landed by-catch, a total of 1.35 kg per kg of *Nephrops* landed of which 0.82 kg were undersized *Nephrops* and 0.53 kg were undersized fish. The discard of undersized fish was hence 87% lowerand total discards (i.e. including *Nephrophs* discards) were 70% lower compared to the conventional trawl. The higher discard of *Nephrops* is due to that the selective fishery occurs mainly on national waters which are located closer to the coast and therefore are fished more intensely. The landed by-catch decreased from 73% in weight to 6.6 % (Valentinsson, unpubl.). The main species discarded during selective trawling were *Nephrops*, dab (*Limanda limanda*), long rough dab (*Hippoglossoides platessoides*), plaice (*Pleuronectes platessa*), cod (*Gadus morhua*), whiting (*Merlangius merlangus*), witch (*Glyptocephalus cynoglossus*), hake (*Merluccius merluccius*), flounder (*Platichtys flesus*) and gurnard (*Eutriglia gurnardus*).

Discards in the creel fishery are lower, 0.36 kg per kg of Norway lobster landed (Anon.2006). Of this, 0.21 kg is undersized *Nephrops* and 0.15 kg is undersized fish. A great part of the fish can be assumed to die, while 99% of the discarded creel caught lobsters survive (Wileman et al. 1999), hence around 0.15 kg (assuming 100% mortality in lack of other figures) of fish discard is killed per kg of creel-caught *Nephrops* landed. In the creel fishery the main species discarded were *Nephrops*, cod, sea scorpion (*Myoxocephalus scorpius*), swimming crab (*Liocarcinus depurator*), spider crab (*Hyas* sp.), edible crab (*Cancer pagurus*), poor cod (*Trisopterus minutus*), whelk (*Neptunea antiqua*), hermit crab (*Pagurus bernhardus*) and squat lobster (*Munida rugosa*).

The discarding of these mostly commercially valuable species is a waste not only of biological but also of economical resources as these individuals could have grown and been part of the commercial catch one or a few years later.

Natural resources

Although abiotic resources were characterised, a number of both biotic and abiotic natural resources used in the life cycle of this product such as crude oil (used for diesel production and production of plastic materials like LDPE, nylon and PP) and copper (used as anti-fouling agent) as well as steel and iron (used for the fishing gear) are lined up in Table 2.

Table 2. Some natural resources needed for the production of Norway lobsters

Resource use	**Unit**	**Amount used per FU**		
		Creel fishing	Conv. trawling	Selective trawling
Crude oil	kg	3.0	9.3	4.9
Uranium	mg	20	33	24
Coal	kg	0.30	0.44	0.24
Cu	g	1.0	2.1	1.3
Iron	g	134	76	39
NaCl	g	229	16	13
Seafloor area swept	m^2	1.8	33000	15600
Discard killed	kg	0.15	4.5	1.4
Herring (bait)	kg	1.1	0	0

Secondary energy

Secondary energy means only the direct input of energy into the system is counted (fuel, electricity), not the background energy used for production of supply materials etc. The energy consumption in the fishery is extraordinary (see Fig. 6). Using an energy content of diesel oil of 42.8 MJ/kg diesel and a diesel density of 845kg/m^3 gives a direct energy consumption in the fishery of 324 MJ/kg of conventionally trawled Norway lobster and 79 MJ/kg of creel-fished lobsters (around 10% of the latter are due to the herring bait fishery). With regard to the species-selective trawl, the different catch composition makes the selective trawl much more resource efficient compared to the conventional one. The species-selective trawl fishery requires 154 MJ to provide the same amount of Norway lobster. The other life-cycle phases are completely over-shadowed by the diesel consumption in the fishery. After landing, an additional 37 MJ/kg of Norway lobster are used for boiling and cooling at the auction, wholesaler and retailer and for transporting the product to the consumer by car. Energy use after landing represents 10% of total energy use for conventionally trawled Norway lobsters, 19% for selective trawling and 32% for creel-fished Norway lobsters. Obviously, there is a pronounced difference in energy use between the fishing methods, which can be seen in Figure 6. For the underlying fuel consumption figures, see section 4.1.1.

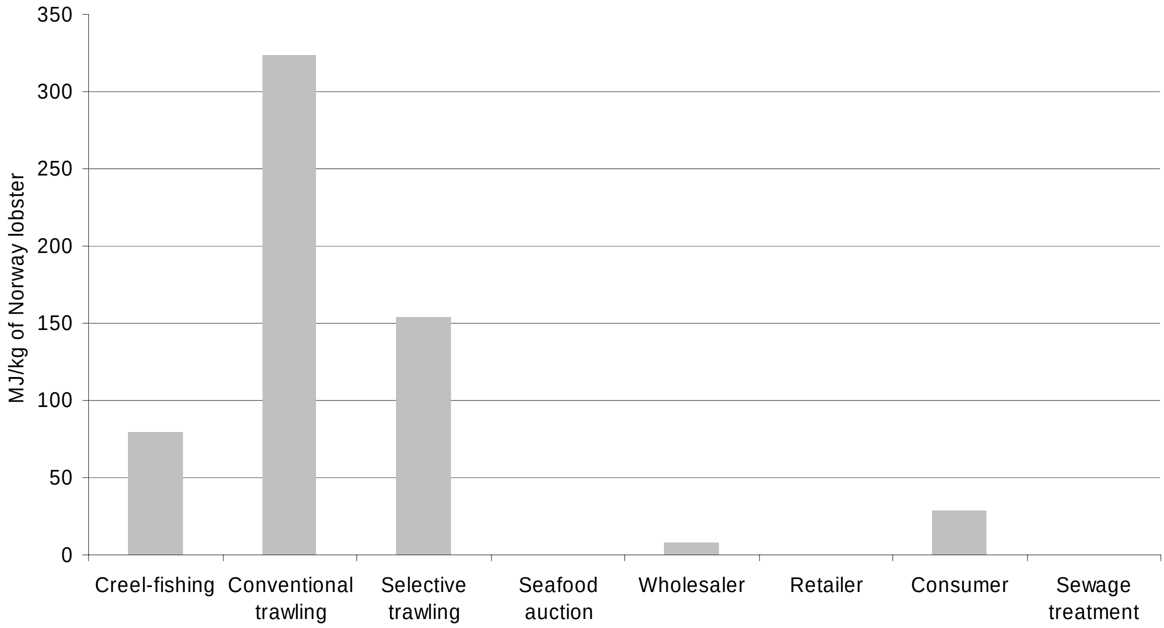


Fig. 6 Energy use in the life cycle of a kilogram of Norway lobsters. Creel-fishing, conventional trawling and selective trawling represent alternatives.

4.1.9 Product loss

A general inventory result is that product loss is very low, close to zero. This is of course due to the high economic value of the product, creating incentives to avoid waste of it. There is no quantifiable product loss in none of the included life cycle phases, although small losses of course occur from time to time. As one of the wholesalers put it when asked about product waste “If I have a difference in amount of lobsters going in and out, I have a big problem”.

4.2 Impact Assessment results

4.2.1 Overall life cycle

Most categories of environmental impact are dominated by the fishery, mainly due to the diesel production and combustion in the creel fishery, see Fig. 7. This is even more pronounced in the case of trawling, see Figures 8 and 9. For the most important processes contributing to these results, see Table 3.

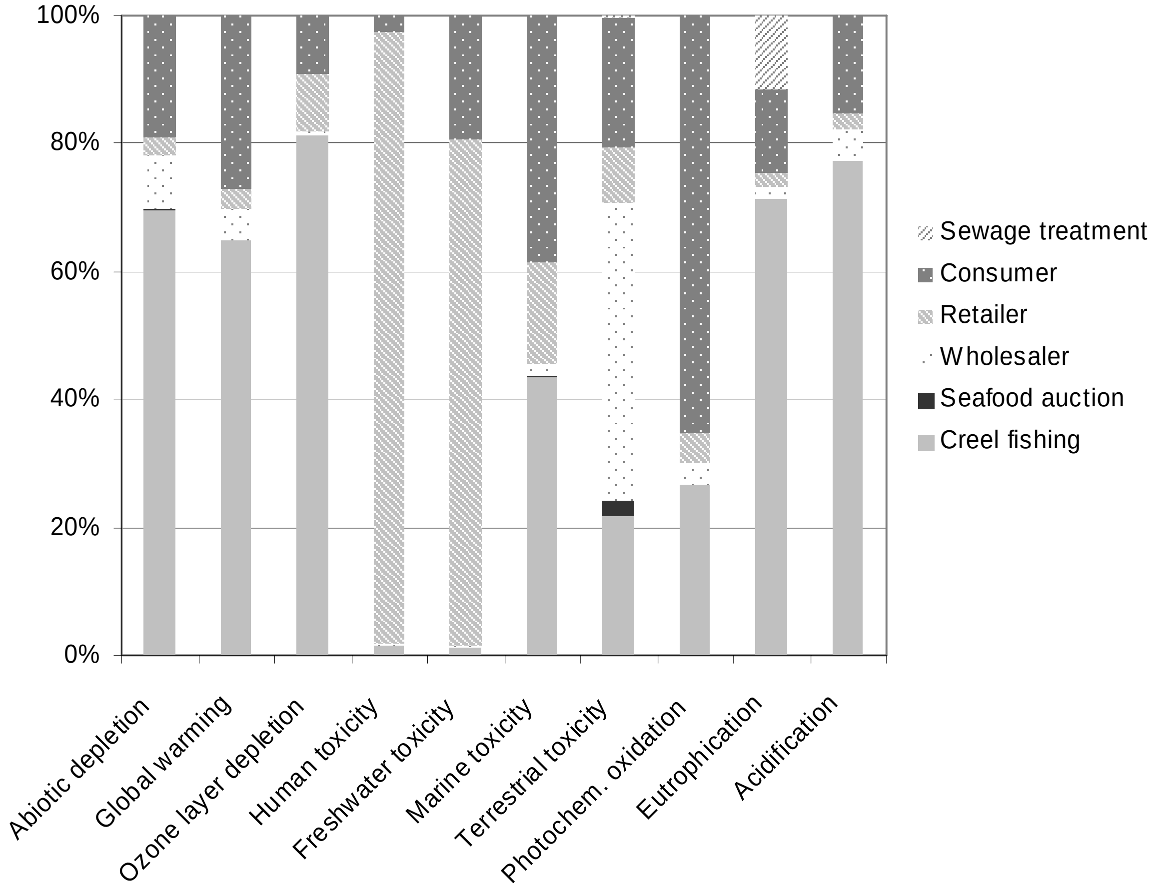


Fig. 7 Overall results of characterisation for the creel-fished Norway lobsters.

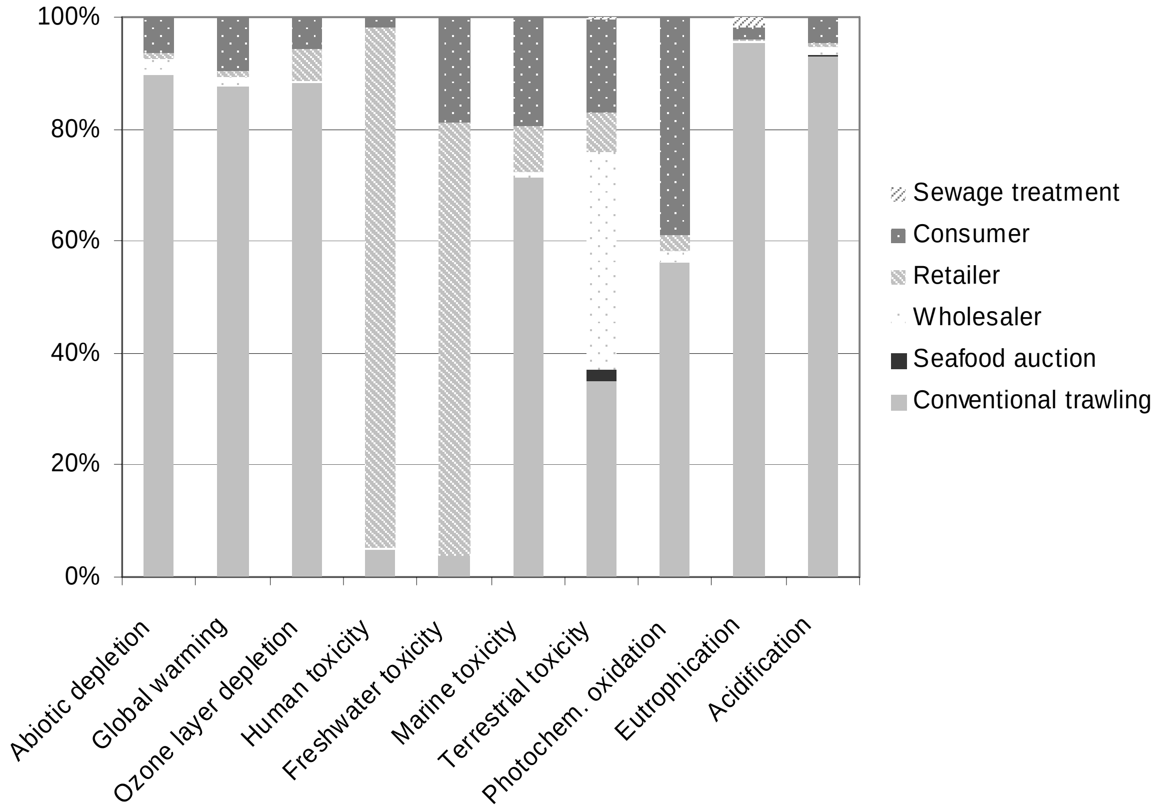


Fig. 8 Overall results of characterisation for conventionally trawled Norway lobsters.

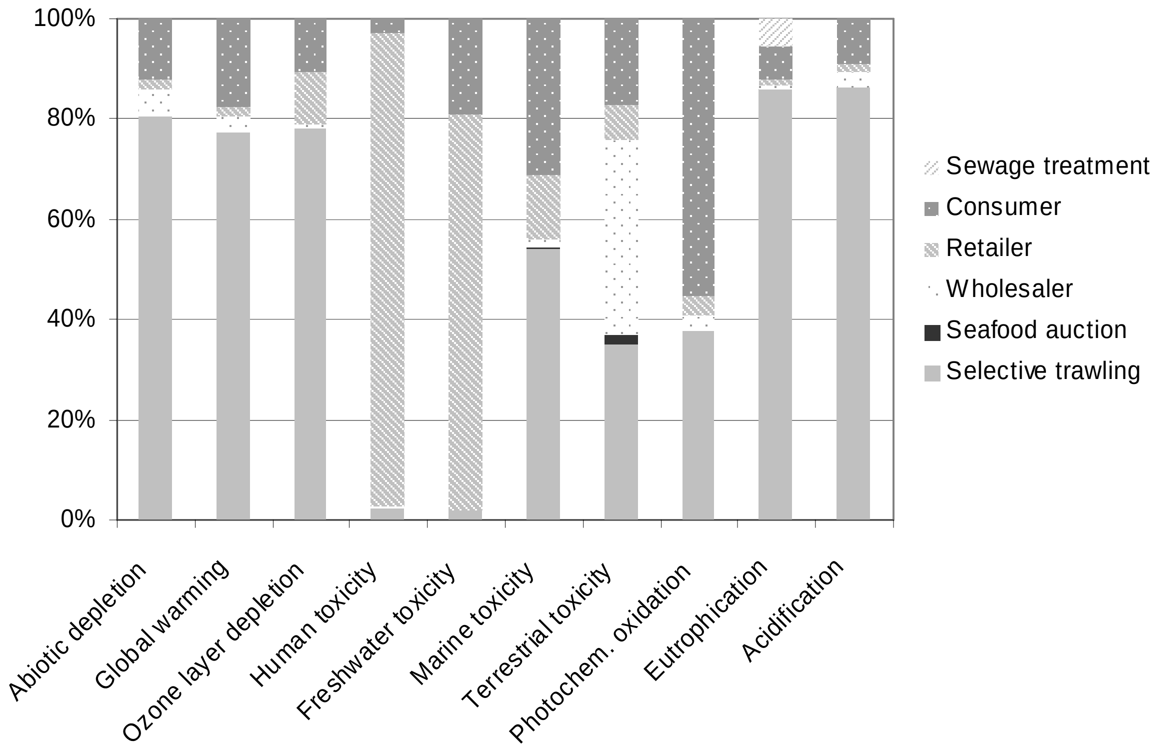


Fig. 9 Overall results of characterisation for Norway lobsters fished with selective trawls.

4.2.2 Global Warming
For conventionally trawled Norway lobster 88% of emissions causing global warming are formed in the fishery. This is mainly due to emissions from diesel combustion (76%), emissions related to diesel production (12%) and the home transport. The same holds true for creel-fishing but in this case the fishery represents “only” 65% of global warming emissions. An additional contributor in creel-fishing is municipal waste incineration and the bait ranking fourth and fifth, the latter representing 5% of the global warming emissions throughout the life cycle.For Norway lobsters caught by selective trawls, 77% of the global warming emissions were caused in the fishery.

4.2.3 Eutrophication
The fishery, with its emissions of NO_x, is also responsible for the main part of eutrophying emissions. The results are similar to global warming in that diesel combustion was most important, diesel production second and the home transport third (except for creel-fishing, see Table 3). For conventionally trawled Norway lobsters, fishery represented 95% of eutrophying emissions, for creel-fished 71% and for Norway lobsters caught by selective trawls 86%.

4.2.4 Acidification
Acidifying emissions such as SO_x are likewise mainly formed in the fishery due to fuel combustion, therefore the main contributors are again diesel combustion, diesel production and transportation to the household for all cases.

4.2.5 Toxicity (Human, Freshwater, Marine and Terrestrial)
It is recognised that uncertainties regarding the impact assessment methodologies for toxicity are large. Marine toxicity is dominated by fishery due to fossil fuel use and copper emissions from anti-fouling paint (the latter representing 21% of total marine toxicity in conventional trawling and 13% in creel fishing). The pattern is similar in Terrestrial toxicity where the seafood auction and the wholesaler play a small role due to electricity consumption. However, it was surprising to find that both human and freshwater toxicity were completely dominated by the retailer and the production of the LDPE (25g!) used as packaging in this phase. This could either indicate that there were very few emissions causing Freshwater and Human toxicity in other processes or that some substance involved in LDPE production is considered to cause high Freshwater and Human toxicity. To investigate this, I decided to exchange the data for LDPE production in the sensitivity analysis following in section 4.3.

4.2.6 Photochemical Oxidation
In Photochemical oxidation, the rare thing happens, that the consumer phase dominates, at least in the case of creel fishing (representing 65% of total PCO) and selective trawling (55% of total PCO). For conventionally trawled lobsters, the fishery is most important (56% of total PCO). Production of fossil fuels, especially gasoline (used in the home transport to the consumer) determines this result. For creel-fished lobsters, production of the gear materials also contributes (ranking fourth most important process).

4.2.7 Abiotic resource depletion
With regard to abiotic resource depletion, fishery is again the dominant phase. This is due to diesel production, the home transport and the wholesaler with production of the polypropylene bucket and LPG production (used for boiling the lobsters).

4.2.8 Ozone layer depletion
I did not obtain data of refill of cooling agents in any life cycle phase, supposedly due to that is was not refilled and hence there was no consumption and no emissions. However, this was probably an underestimation. The only cooling agent data added manually (i.e. which did not come from databases) turned out to dominate the results in this category, namely the cooling agent used in the herring fishery (ending up as bait in the creel fishery). There is no reason to believe that the use of cooling agents in this fishery is extreme compared to e.g. the wholesaler or in the Norway lobster

fisheries themselves, therefore the results in this category are considered unreliable and will not be discussed further.

Table 3 The three most important processes in six of the environmental impact categories

Impact category	**Fishing gear**	**Most important process**	**Second most important process**	**Third most important process**
Global Warming	Conv. trawl	Diesel combustion	Diesel production	Home transport
Global Warming	Selective trawl	Diesel combustion	Home transport	Diesel production
Global Warming	Creel	Diesel combustion	Home transport	Diesel production
Eutrophication	Conv. trawl	Diesel combustion	Diesel production	Home transport
Eutrophication	Selective trawl	Diesel combustion	Diesel production	Home transport
Eutrophication	Creel	Diesel combustion	Home transport	Diesel production
Acidification	Conv. trawl	Diesel combustion	Diesel production	Home transport
Acidification	Selective trawl	Diesel combustion	Diesel production	Home transport
Acidification	Creel	Diesel combustion	Diesel production	Home transport
Marine toxicity	Conv. trawl	Diesel production	Diesel comb./ Antifouling emissions	Municipal waste incineration
Marine toxicity	Selective trawl	Diesel production	Diesel comb./ Antifouling emissions	Municipal waste incineration
Marine toxicity	Creel	Diesel production	Municipal waste incineration	Home transport
Photochemical oxidation	Conv. trawl	Diesel production	Home transport	Diesel combustion
Photochemical oxidation	Selective trawl	Home transport	Diesel production	Diesel combustion
Photochemical oxidation	Creel	Home transport	Diesel production	Diesel combustion
Abiotic resource depletion	Conv. trawl	Diesel production	Home transport	PP/LPG production[1]
Abiotic resource depletion	Selective trawl	Diesel production	Home transport	PP/LPG production[1]
Abiotic resource depletion	Creel	Diesel production	Home transport	PP/LPG production[1]

4.3 Sensitivity analysis

Some figures emerge as more important than others for the characterised results. These include the fuel consumption in fishery, the economic value upon which economic allocation was based and the product exchange from whole Norway lobster to edible meat. In addition, the choice of impact assessment as well as the choice of database data could be important. Therefore, these factors were chosen to be included in the sensitivity analysis of which a brief description follows. It was chosen to focus on the most relevant impact categories in the selectivity analysis, i.e. where the new data can be expected to change the results most.

4.3.1 Fuel consumption

The fuel consumption was in both fisheries the single most important figure determining the final characterised results of the study to a large degree. Therefore, we tried to use the maximum and minimum values (± one standard deviation (SD)) to evaluate the importance of the fuel consumption figure on Global Warming results. Global Warming is representative also for Abiotic resource depletion, Eutrophication and Acidification as the resource use/emissions determining them are directly proportional to the fuel consumption. The result of this exercise is shown in Table 3.

Table 3. GWP_{total} in the three analysed fisheries when the fuel consumption is varied one SD above and below the average (figures in brackets are fisheries proportion of total life cycle GWP value)

	Conventional trawl	**Selective trawl**	**Creel**
Base case (average):	31.7 (88%)	17.0 (78%)	11.1 (65%)
One SD higher:	49.6 (92%)	25.5 (85%)	15.2 (74%)
One SD lower:	13.8 (72%)	21.6 (55%)	6.96 (44%)

The impact is considerable, when the fuel consumption in trawling is one SD lower and one SD higher in creel fishery, they switch places and creel-fishing then leads to more Global Warming emissions than does trawling. On the other hand the difference between the fishing methods was significant, why the described situation represents an extreme and unprobable case. When fuel consumption is as low as 53 kg diesel per 100 kg of catch in creel fishery, it causes similar amounts of Global Warming emissions as does the 10 km car transport from the retailer. It was calculated that a car trip of 100 km corresponded to the energy use for average conventional trawling one kg of Norway, for creel-fished *Nephrops* the distance when the energy consumption for the home transport and the average fishery equalled was 26 km.

4.3.2 Allocation data

The allocation method itself was not tested as it is quite obvious that completely different results would have been obtained had we used allocation based on energy content or mass (Norway lobsters represented 59% of value of trawl catch but only 27% of mass and approximately 28% of edible energy content (Anon. 1986)). Such approaches would, in my opinion, have led to less accurate results, since it would have taken a lot of the burden away from Norway lobsters, while the lobsters are the true reason for the existence of this fishery and the economic value reflects the fisherman’s incentive for going out fishing, not the mass or energy content of the landed by-catch (in conventional trawling cod, saithe and whiting; in selective trawling plaice, cod and sole and in the creel fishery edible crab and mixed fish). System expansion poses another alternative, but was considered not being feasible since no systems exist where each by-catch species is caught alone and the iterative process suggested by Thrane (2004a, 2004b, 2006) was considered to be beyond the scope of this work. Therefore we chose to rely on Thrane’s conclusion that economical allocation is a fairly good proxy in many cases (Thrane 2006), in this case representing the most accurate division between main product and by-products.

Therefore, in the sensitivity analysis of allocation, focus is on the data upon which the economical allocation is based in the fishery. The value used for economical allocation was the average first hand landing value during two years (2002-2003), taken from the statistical database at the National Board of Fisheries. In the base case, Norway lobsters accounted for 59% of the environmental burden of the conventional trawl fishery and for 99% of the creel fishery. We tried to replace this proportion by the average value as reported by the questionnaire weighted according to the relative amount landed by each gear type (as opposed to just calculating an average of the gear types involved) which was 70% for the conventional trawl fishery and 86% for the creel fishery. The result was that the difference in GWP_{total} between the fishing methods increased further; conventional trawling increased from 31.7 to 36.7 kg CO_2 eqs and the creel fishery decreased from 11.1 to 10.1 kg CO_2 eqs. The difference within the fishing methods when allocating based on the questionnaire replies was in both cases 12%.

Another allocation decision which had great impact on overall results was the allocation of the transport from the retailer to the consumer. There was no data on the division between Norway lobsters and other food items bought at the same shopping occasion and, as a worst case, the entire car transport was allocated to the lobsters. It is a luxurious food normally not consumed many times per year, therefore I guessed that the consumer would probably be willing to go to town by car only to buy the lobsters. In the sensitivity analysis I chose to allocate only 50% and 10% of the home transport to the lobsters just to see how much this would change overall results, these values were not based on any information about shopping habits. In this case, both Global Warming and Photochemical Oxidation were analysed since the car transport previously had been found to be important in this impact category. As the difference between the fishery and the consumer phase were smallest between creel fishery and the consumer, only the creel case was analysed here. The results of the sensitivity analysis can be found in Table 4, where it is evident that the allocation in the home transport is important.

Table 4. Sensitivity analysis of allocation value used in the car transport from the retailer to the consumer with regard to Global Warming and Photochemical Oxidation (only creel-fishing). Values in brackets are the proportion represented by the consumer phase (of total life cycle emissions).

	GWP total (kg C_2H_4 eqs.)	**PCO total** (kg C_2H_4 eqs.)
Base case (100% allocated to NL)	11.1 (27%)	3.5E-3 (65%)
50% allocated to NL	10.1 (20%)	2.3E-3 (48%)
10% allocated to NL	9.3 (13%)	1.4E-3 (16%)

4.3.3 Product exchange

The product exchange found in literature and used in the study was 30% (Thrane 2004a, Anon. 1986), however in our own experiments it was higher 37-43%. We tried 40% in the sensitivity analysis to see the effect on results of this change. As the functional unit was 300 grams of lobster tail meat, a 40% product exchange means that only 0.75 kg of lobsters are needed to obtain the functional unit instead of one kilogram. In this case both trawling and creel-fishing were included and the changes with regard to Global Warming were analysed. Conventionally trawled lobsters had in the base case caused 32 kg CO_2eq, with 40% product exchange this figure decreased to 23 kg CO_2 eqs. Creel-fished lobsters had in the base case caused 11.1 kg CO_2 eqs. A product exchange of 40% lead to a decrease to 8.3 kg CO_2 eqs. This demonstrates how important maximising the product exchange (and minimising product waste) can be for overall environmental impact.

4.3.4 Impact Assessment method

To evaluate the importance of the impact assessment method chosen, another one was used, namely Eco-indicator 99 (E) and the categories corresponding most closely to the CML method were compared (Climate Change, Minerals, Fossil fuels, Acidification/Eutrophication and Ecotoxicity). The results are best illustrated graphically, see Figs. 10 and 11.

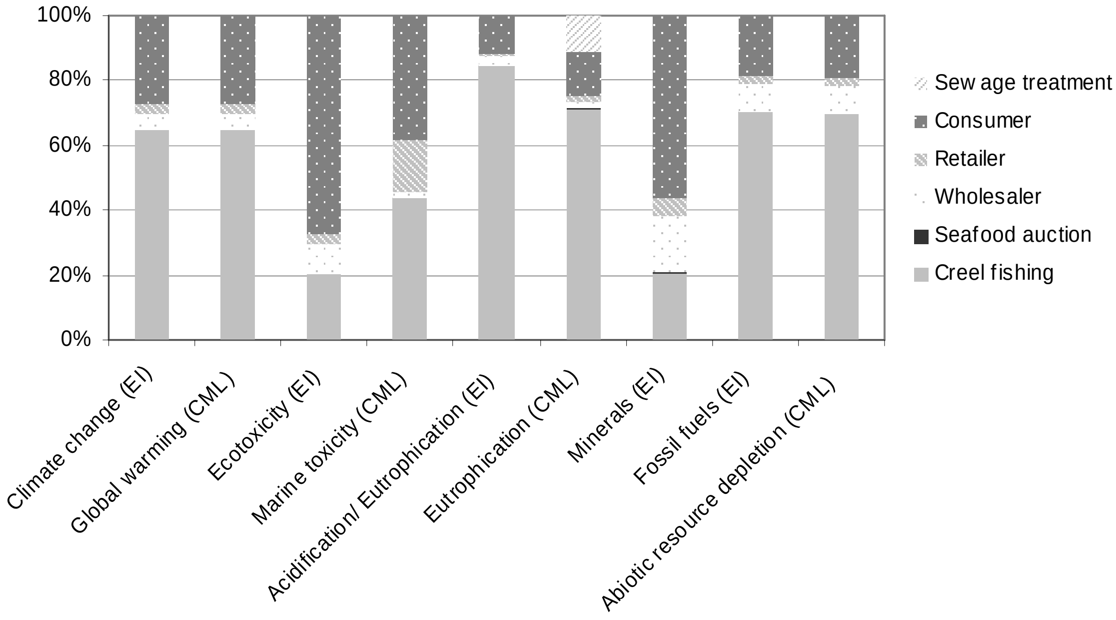


Fig.10 Sensitivity analysis of the impact assessment method for creel-fishing, comparison between CML and Eco-indicator 99 methods.

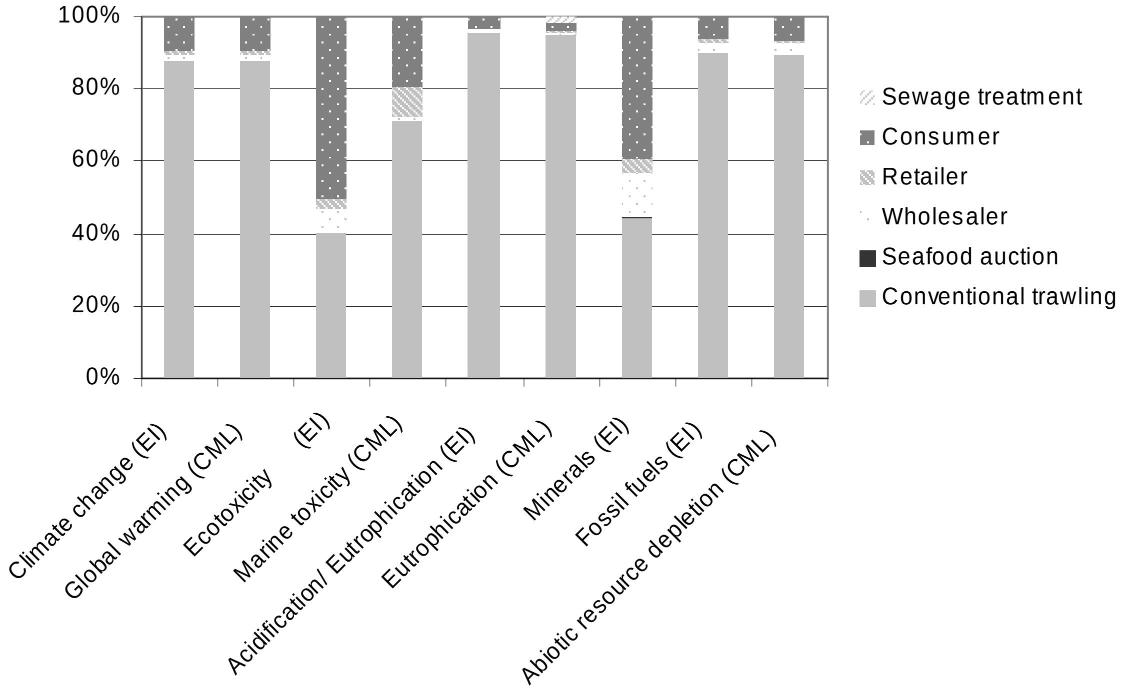


Fig. 11 Sensitivity analysis of the impact assessment method for trawling, comparison between CML and Eco-indicator 99 methods.

This analysis shows that the methods correspond fairly well for the compared categories. Climate Change (EI) and Global Warming (CML) give almost identical results. Ecotoxicity (EI) and Marine toxicity (CML) are similar but emissions to water have higher indicators in Marine toxicity resulting in greater importance of the fishery. Acidification/Eutrophication (EI) and Eutrophication (CML) are also almost identical, nutrient emissions from sewage treatment are weighted higher when eutrophication is treated separately, as in CML method. In Eco-indicator, abiotic resource depletion is separated into two impact categories; Minerals and Fossil fuels. Abiotic resource depletion corresponds well with the category Fossil fuels, while Minerals gives larger weight to the phases Consumer and Wholesaler. Fossil fuel use dominates the resource use in the studied system and therefore characterisation in Abiotic resource depletion. In conclusion, I feel confident that the same main results had been found, had Eco-indicator 99 been used for Impact Assessment.

4.3.5 Database data

The LDPE data was exchanged to data from another database (BUWAL 250). This lead to completely different results in the categories human and freshwater toxicity (Fig.12) which were previously dominated by the LDPE production included in the Retailer phase. This indicates that the data source and the impact assessment method are important for this impact category. Results of toxicity impact assessment are considered to be highly uncertain and will not be discussed further.

Change of diesel data (from Ecoinvent to BUWAL data) led to minor differences only, while change of data for the passenger car from Ecoinvent to BUWAL caused an increase in GWP of the home transport by 23%, and an increase in importance of the home transport from 9% to 11%.

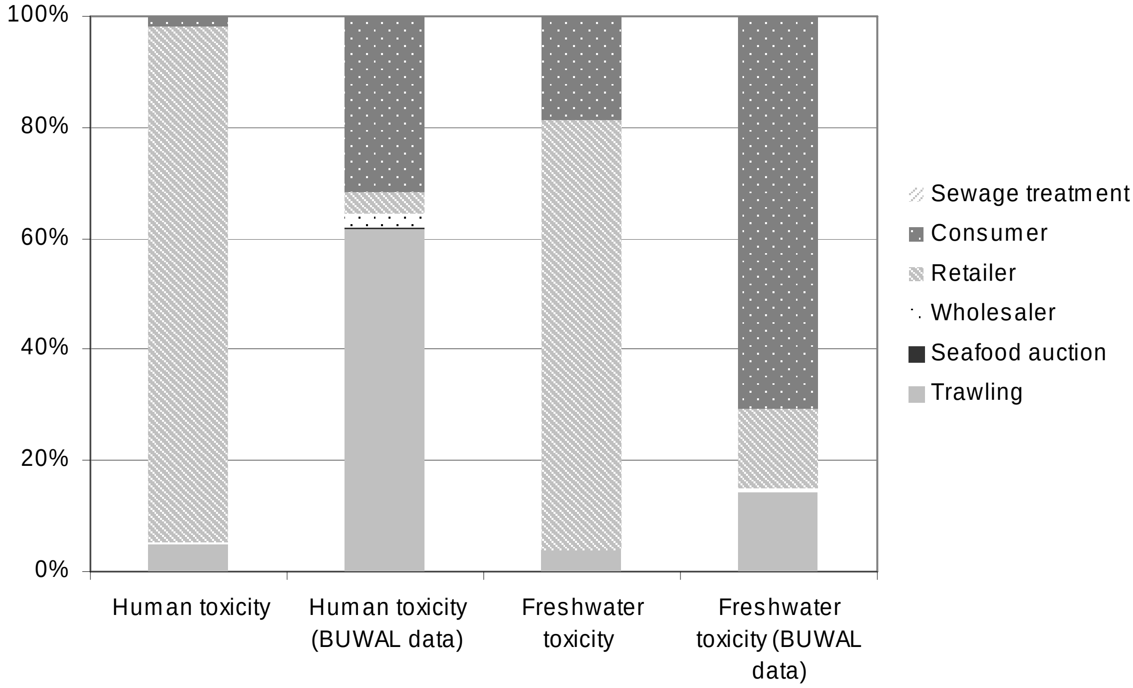


Fig. 12 Comparison of results for Freshwater and Human toxicity using LDPE data from the database BUWAL.

5. DISCUSSION

5.1 Overall results

Fishery, with its high fuel consumption, dominated the life cycle both for creel-fishing and the two cases of trawling just as has been shown for many other types of seafood (Ziegler and Nilsson, unpubl).The difference was that fishery, especially the trawl fishery, was even more important compared to later life cycle phases due to the extraordinary fuel consumption in this fishery, almost nine liters of diesel per kilogram of Norway lobster landed in conventional trawling, 4.3 in selective trawling. Thrane (2004a) found a fuel consumption of around six liters per kilogram of Norway lobster landed in Danish fisheries while Tyedmers (2001) found a much lower energy consumption 37 MJ/kg corresponding to less than one liter of diesel. The latter is probably due to that Norway lobster was not the primary target species of the investigated fishery (which was cod) and that mass allocation was used to divide the fuel use between cod and Norway lobster.

5.2 Impact on the Norway lobster stock

The use of the Norway lobster stock on the Swedish west coast is currently considered to be sustainable but it is recommended that fishing mortality should not increase due to uncertainty about the stock status in relation to threshold values (Ask and Westerberg 2006). The composition of the landed *Nephrops* catch is biased towards more males both in the creel fishery and in lobster trawl landings, it consists of around 70% males and 30% females (M. Ulmestrand, pers. comm.). Of the females landed, a higher percentage is berried (carrying roe) in creel fisheries than in trawls. The berried females normally live in their burrows, but they seem to be attracted by the bait and therefore enter the creels. This overrepresentation of berried females in the catches is discussed as one potential negative aspect of the creel fisheries since there is a risk of recruitment overfishing should the creel fishery grow rapidly (i.e. that not enough eggs are produced). Since the discard survival is very high for creel-fished *Nephrops* (described in section 5.4), a way to mitigate this could be to protect berried females (as is implemented in the fishery for European lobster, *Homarus gammarus*).

5.3 Baiting

One aspect that was not expected to have such importance was the baiting of creels with salted herring which was responsible for 10% of the total fuel use in the creel fishery and 5% of the global warming emissions caused throughout the life cycle of the creel-fished lobsters. The amounts of bait used were higher than the amount Norway lobsters caught. As small (undersized) lobsters can enter the creels to feed on the bait and then leave the creels again, this could be viewed as an input of nutrients to the marine ecosystem- or as a type of semi-aquaculture where small lobsters are fed herring to grow to commercial size. A considerable part of the bait is, however, left in the creels when hauled and seabirds happily consume it when discarded (it has to be exchanged since it does not “smell” after a couple of days in the water). There are no studies on the amount of the bait actually consumed by the catch and the part leaving the creels with undersized specimens but it can be assumed to be considerable. The use of artificial bait (flour-based dough with fish oil) could be an improvement option to consider for the creel fishery.

5.4 Discard

The discard in *Nephrops* trawl fisheries is a recognised problem. Actually, the northeast Atlantic trawl fishery for *Nephrops norvegicus* has the fifth highest discard ratio in the world (Catchpole et al. in press). The amount discarded is much higher than the amount landed (4.5 kg/kg of *Nephrops* from conventional trawling) and the number of individuals killed per individual landed is even higher since the discarded specimens are smaller. With the exception of creel-caught *Nephrops* (which survives discarding, see below) discarding is a waste of a limited biological resource. The individuals discarded will almost exclusively die and could, if left in the sea, have been part of the landed catch one or a few years later. The most critical part of the discard is undersized Norway lobsters and cod. Cod stocks are on historically low levels in this area and ICES has repeatedly since 2003 recommended a complete fishing stop for cod. Of discarded trawled Norway lobsters, 75% are by the ICES working group for *Nephrops* stock assessment estimated to die, probably mostly due to physical damage and stress. For roundfish, mortality is total (100%) in part due to expansion of the air bladder in fish when taking them to the water surface. No difference was made between conventional and selective trawling with regard to natural and discard mortality. Regarding the contribution to eutrophication of the discard, even though the landed catch represents an outtake of nutrients from the sea, this fishery causes an increase in the biological turnover of nutrients and contributes to eutrophication processes in the area due to the high amount of discard.

Discard in the creel fishery is largely unknown. In 2005 sampling was done during 18 fishing trips with creel fishing vessels to study the catch composition (M. Ulmestrand, pers.comm.). It was found that around 0.36 kg of biomass was discarded per kg of *Nephrops* landed, 0.21 kg of which was undersized *Nephrops* and 0.15 kg was undersized fish. Of the *Nephrops* discard in the creel fishery, 99% have been found to survive (Ulmestrand et al. 1998). Due to the expansion of the air bladder in fish when taking them to the water surface, mortality for roundfish discard is probably high, but somewhat lower than for trawled roundfish (where it is assumed to be 100%). In lack of other figures, it was here assumed to be 100%.

5.5 Seafloor use

The seafloor area swept and permanently affected by trawls per kg of trawled Norway lobster may seem large. It should be considered that *Nephrops* trawling is the dominant type of demersal trawling occuring in the area, but not the only one and that Danish fishermen land more Norway lobster than do Swedes in this area, implying that the total impact of demersal fishing is much larger than presented here, where the intention was to relate the impact to a functional unit of Norway lobsters. However, it is impossible to analyse Danish fishing effort in the same way since effort is not reported with the same geographical resolution. It should also be kept in mind that the recovery time indicated as high in MarLIN is six months to five years, why the use of six months (more than twice per year = permanently disturbed) leads to a conservative estimate of the seafloor impact. This is the first time the method developed in Nilsson and Ziegler (2006) has been applied in a seafood LCA and, to our knowledge, it is the most advanced approach so far to include seafloor impact in an seafood LCA. The impact of a creel landing on the seafloor when it is set is probably smaller per square meter compared to when the same area is swept by a trawl, but the area impacted by creels was evaluated to be impacted equally as trawled areas due to lack of more specific data and since there was such a big difference already in the areas covered by the respective fisheries.

5.6 Data uncertainty/representativity

A limited number of vessels 7/36/147 trawlers and 12/42/99 creel vessels (No. used questionnaires/No. fishermen who received questionnaire/No. vessels active in fishery) participated. The vessels participating in this study land around 8 and 21% of trawled and creel-fished lobster, respectively. As the difference in the most important figure, the fuel consumption, was so pronounced between the two groups and showed relatively low variation, the data are regarded as reliable even though representing a small sample size. There is a risk that there is a bias due to the way data were collected: by the questionnaire. There is a possibility that fishermen who are interested in participating in this study are not representative, i.e. have higher or lower resource use than the "average fisherman". However, due to the large difference between the gear types and small variation within them, this is considered being unlikely. An alternative would have been to randomise and simply go out collecting data for a certain number of vessels, but I believe that the voluntary basis of the questionnaire increased likelihood of true answers and have prioritized collaboration with fishermen.

5.7 Catch quality

A study of the quality of lobsters fished by creels and trawls respectively showed that there was a significant difference between the quality of Norway lobsters caught by creels and trawls (Evenbratt, 2005). Creel-caught lobsters were in a better condition from the beginning and aged more slowly than their trawled relatives, they were also larger (all of which explains why they achieve higher prices). The quality assessment method used was QIM (Quality Index Method) of which the scheme for Norway lobster is still under development and not fully validated, but was kindly made available by RIVO-DLO, the Netherlands (R. Schelvis, pers. comm.). In a comparative LCA one would ideally like the products to be identical with regard to function and quality. In this case the quality of the products of the two fishing methods were shown *not* to be identical. The fishing method with the least resource use and emissions also had the highest catch quality, meaning that more of the catch will reach the end consumer and less of it end up as product waste. This underlines the earlier conclusion in this study that creel-fishing of lobsters is less resource-intensive than trawling.

5.8 Risks in fishery

Trawling is a more automatised procedure than is creel-fishing. Setting and hauling of creels has to be done by a person on deck and working conditions are often from an ergonomic and safety point of view, far from optimal (H. Aasjord, pers.comm.). Being a fisherman is a high-risk profession and fatal accidents are more common on the smaller vessels deploying passive fishing gear than on the larger, more industrialised vessels, while less serious accidents are more common on larger vessels such as trawlers (H. Aasjord, pers.comm.).

An additional risk is the loss of gear or gear material which must be considered higher in creel fishery (Anon. 2001) than in trawling and can be a part of the explanation of the high use of gear material in this fishery. Lost creels and nylon net can keep trapping animals, especially if there is still bait inside, subsequently killing them, a process termed ghost-fishing (Anon. 2001). Ghost-fishing is a problem of some passive fishing gear types, especially of gillnets. The use of degradable gear materials in creels and gillnets has been proposed as a mean to avoid this risk (Anon. 2001).

5.9 Improvement options

Assuming that the negative aspects of creel-fishing with regard to safety and working conditions as well as the risk of recruitment over-fishing can be managed, the primary environmental improvement option is to increase proportions of creels and selective trawls in the Swedish *Nephrops* fishery. The only difference included in the calculations for the selective trawl was the changed catch composition (lower fish discard and higher proportion of Norway lobster in the landings). Other changes, such as higher landings per unit of effort can be expected but were not included due to difficulties in quantifying them. Therefore, the major difference between the conventional and the selective trawl represent a major improvement option for the trawl fishery. The present study has shown how LCA, in a relatively straightforward way, can be used to evaluate environmental consequences of the introduction of technical regulations in a fishery once basic LCA data is gathered.

A general improvement option is to save fuel. This could be accomplished by fuel-saving vessel design and operation (Ziegler and Hansson, 2003; Hassel et al., 2001). An additional improvement option in the fishery is that household waste should be brought ashore.

A considerable part of the environmental burden of the creel-fished lobsters was due to the bait used (around 10%), hence minimising the use and especially the waste of bait clearly represents an improvement option. The use of materials for the creels was high, as has been shown for other passive gear types in the case of a gillnet cod fishery (Ziegler et al. 2003). Loss of gear material also represents risk of ghost-fishing, as explained above. Therefore, technical improvements maximising the lifetime of creels and decreasing the need for replacing them is an improvement option worth considering as is the use of artificial bait made of flour-based dough with fish oil to attract the lobsters. Due to high discard survival in the creel fishery, it is important that both undersized fish and crayfish are actually discarded and not used as bait, pet food or consumed.

After landing, it was shown that the product exchange from whole lobsters to edible meat and the home transport were the two main aspects determining the environmental impact after landing. Therefore, the consumer has great influence on the overall environmental impact of Norway lobsters both by choosing lobsters caught at lowest possible environmental costs and highest possible quality in the seafood counter and through his or her own behaviour when buying and consuming the lobsters. This means avoiding car transports when possible and making sure that as much as possible of the seafood is actually consumed rather than wasted.

If you have questions or comments after reading this report,
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Acknowledgements
I would like to thank a number of persons who have helped me in gathering data for this study. First of all and most importantly the 19 anonymous fishermen who most kindly provided me with their data. A very special thank you to Uno and Inge Helldner who took me out to creel-fish and taught me a lot of things. Robin Lundgren at the National Board of Fisheries provided me with invaluable data on catches, gears used and addresses to the fishermen. Following the life-cycle; Ilona Miglavs and Gunnar Witzel at the Gothenburg seafood auction were helpful in looking up my impossible questions, as were Ingemar Karlsson at Fiskebäck Seafood AB, Daniel Svensson at Lerøy-Allt i Fisk AB and finally Dennis Ek at the supermarket Coop Konsum Avenyen. Håkan Jansson at Totalteknik AB was one of few manufacturers of cooling equipment who was enthusiastic about answering my many questions and helped me far more than initially planned. Thank you also to Hanne Evenbratt for performing the QIM assessments with great patience even when it meant being at the seafood auction at six o’clock in the morning or sniffing at lobsters that had obviously seen their best days.

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APPENDIX

Table 5. Total characterisation results for the conventional trawling base case (characterisation method CML)

Impact category	Abiotic depletion	Global warming	Ozone layer depletion	Human toxicity	Freshwater toxicity	Marine toxicity	Terrestrial toxicity	Photochem. oxidation	Eutrophication	Acidification
Unit	kg Sb eq	kg CO_2 eq	kg CFC-11 eq	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	kg C_2H_4 eq	kg PO_4 eq	kg SO_2 eq
Trawling	0.18	27.8	3.49E-06	3.05	0.288	3460	0.0106	0.00325	0.0767	0.181
Seafood auction	1.32E-4	0.00881	3.87E-10	0.00600	4.73E-4	2.11	5.93E-4	2.84E-06	6.14E-06	8.06E-05
Wholesaler	0.0059	0.540	1.20E-08	0.133	0.0111	49	0.0117	0.00012	0.000245	0.00293
Retailer	0.00108	0.357	2.21E-07	56.3	5.80	389	2.19E-4	0.000165	0.000309	0.00136
Consumer	0.0129	2.98	2.24E-07	1.05	1.41	944	0.00506	0.00226	0.00173	0.00902
Sewage treatment	9.61E-06	0.00183	2.33E-10	0.0013	1.61E-04	0.97	5.55E-05	2.86E-07	1.50E-03	6.83E-06
Total	0.201	31.7	3.95E-06	60.6	7.51	4850	0.0421	0.0058	0.0805	0.194

Table 6. Total characterisation results for the creel-fishing base case (characterisation method CML). Seafood auction to sewage treatment are identical to Table 5.

Impact category	Abiotic depletion	Global warming	Ozone layer depletion	Human toxicity	Freshwater toxicity	Marine toxicity	Terrestrial toxicity	Photochem. oxidation	Eutrophication	Acidification
Unit	kg Sb eq	kg CO_2 eq	kg CFC-11 eq	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	kg C_2H_4 eq	kg PO_4 eq	kg SO_2 eq
Creel-fishing	0.0474	7.18	1.99E-06	0.907	0.0966	1070	0.00549	0.000922	0.00941	0.0455
Total Creel	0.0681	11.1	2.45E-06	58.9	7.32	2455	0.0251	0.00347	0.0132	0.0589
Selective trawling	0.0852	13.2	1.65E-6	1.44	0.136	1640	0.0106	0.00154	0.023	0.0856
Total Selective	0.1059	17.1	4E-6	58.6	7.27	3025	0.0267	0.00041	0.0268	0.099

Table 7. Total characterisation results for conventional trawling in sensitivity analysis of the characterisation method (characterisation method: Ecoindicator 99 E)

Impact category	Climate change	Ecotoxicity	Acidification/ Eutrophication	Minerals	Fossil fuels
Unit	DALYs	PAF*m^2yr	PDF* m^2yr	MJ surplus	MJ surplus
Trawling	5.83E-06	1.75	1.58	0.0919	31.8
Seafood auction	1.85E-09	0.00842	2.82E-4	0.0013	0.0214
Wholesaler	1.13E-07	0.292	0.0116	0.0253	0.989
Retailer	7.47E-08	0.105	0.00544	0.00799	0.287
Consumer	6.25E-07	2.19	0.0522	0.0809	2.18
Sewage treatment	3.87E-10	0.00139	3.57E-05	1.6E-4	0.00124
Total	6.65E-06	4.34	1.65	0.208	35.2

Table 8. Total characterisation results from creel-fishing and selective trawling in sensitivity analysis of the characterisation method (characterisation method: Ecoindicator 99 E). Seafood auction to sewage treatment is identical to Table 7.

Impact category	Climate change	Ecotoxicity	Acidification/ Eutrophication	Minerals	Fossil fuels
Unit	DALYs	PAF*m^2yr	PDF* m^2yr	MJ surplus	MJ surplus
Creel fishing	1.50E-06	0.661	0.387	0.0291	8.17
Total Creel	2.31E-06	3.26	0.457	0.144	11.7
Selective trawling	2.76E-6	0.828	0.747	0.0435	15
Total Selective	3.57E-6	3.42	0.816	0.159	18.5

(For inventory results don't hesitate to contact me at: fz@sik.se)

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