Journal of Cleaner Production 17 (2009) 416–423

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Eco-labelling of wild-caught seafood products

Mikkel Thrane [a,*], Friederike Ziegler [b], Ulf Sonesson [b]

[a] Aalborg University, Department of Development and Planning, Fibigerstraede 13, 9220 Aalborg Oest, Denmark
[b] SIK, The Swedish Institute for Food and Biotechnology, P.O. Box 5401, SE-402 29 Göteborg, Sweden

ARTICLE INFO

Article history:
Available online 27 September 2008

Keywords:
Fish
Seafood
Eco-labelling
Life cycle assessment
LCA
Sustainable fisheries

ABSTRACT

Several eco-labels for wild-caught seafood have been developed during the last decade. This article describes and analyses the criteria applied by four different eco-labelling schemes for seafood products from capture fisheries, and discusses the criteria in terms of environmental impacts, based on the ISO 14040 standard for life cycle assessment.

It is concluded that the most widespread eco-label, the Marine Stewardship Council (MSC), mainly addresses the fishing stage, in particular the overexploitation of marine resources. LCA studies confirm that the fishing stage represents the most significant environmental burden, but energy consumption and emissions of anti-fouling agents at the fishing or harvesting stage contribute with significant impacts that are not being addressed by international labelling initiatives for wild-caught seafood.

LCA studies show that significant environmental impacts are related to the life cycle stages after landing. This includes fish processing, transport, cooling and packaging (especially for highly processed seafood products). Hence, another challenge would be to include criteria related to the post-landing consumption of energy, certain materials and chemicals, waste handling and wastewater emissions. Minimizing product losses throughout the product chain would also be an important area for future criteria in order to avoid fishing at high environmental costs only to produce something that is later wasted.

The analysis shows that the Swedish KRAV is the only one that currently addresses a range of issues that include energy and chemicals in the whole life cycle of the products. International initiatives such as MSC cover fish products from many parts of the world emphasizing 'overexploitation of fish resources'. It is recommended, however, that international initiatives such as MSC develop criteria related to energy use and chemicals – at least at the fishing stage. Over time, other life cycle stages could be addressed as well to the extent that this is manageable.

1. Introduction

The total global catch of seafood products has increased significantly during the last part of the 19th century but has stabilized on a level slightly above 90,000 tons towards the end of the millennium [1]. Many of the stocks of economic interest are under significant pressure and fishery policies and regulations must be designed to reduce pressure on stocks while meeting the interests of the fishermen and subsequent parts of the product chain from sea to table [2]. Historically, the discussion on sustainability of capture fisheries has mainly been focused on overexploitation and measures such as quota regulation to mitigate overexploitation [3]. This is certainly justified, as fishing is considered to be the most large-scale human alteration of the marine ecosystem [4].

More recently, however, increased attention has been given to effects on multiple species (multi species assessments) and the surrounding ecosystem (ecosystem-based management), by-catch and discard issues, seafloor impacts, lost fishing gear leading to ghost fishing, as well as other types of waste generated from fishing vessels. This is also reflected in the Code of Conduct for Responsible Fisheries (CoC) launched by FAO in 1995. The focus of the Code is on sustainable resource extraction and management, but it also considers ecosystem effects of fishing, food safety as well as social aspects [5]. The publication of the Code has been most important for placing fisheries sustainability on the political agenda. The FAO has since also looked into product certification with or without eco-labelling as a way to promote more sustainable fisheries [6], and in 2005 published a guideline for eco-labelling of seafood products [7].

The expanded view on the notion 'sustainable fisheries' is welcomed, but little attention is given to other important aspects such as energy consumption and the contribution to global warming, which may have a negative effect on the fisheries in the

* Corresponding author. Tel.: +45 30296054; fax: +45 98153788.
E-mail address: thrane@plan.aau.dk (M. Thrane).

0959-6526/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jclepro.2008.08.007

long term.[1] Additionally, there are several environmental aspects to consider in the rest of the product chain as well, which are seldom addressed in the discussion of sustainable fish products [8,9].

Eco-labelling schemes have emphasized food products from agriculture and aquaculture but an increasing number of labelling initiatives for wild-caught seafood have emerged over the last decade [6]. These range from 'single attribute' labels, such as the dolphin safe tuna label, to 'multi attribute' labels that address several environmental aspects at 'one' or 'several' stages of the products' life cycle (from sea to table).

The present article analyses the potential and limitations of different eco-labels of wild-caught seafood products and discusses how a holistic approach to eco-labelling may promote more sustainable seafood products from a life cycle perspective.

2. Conceptual framework and methodological approach

When analysing the environmental impacts from seafood products it is important to distinguish between impacts occurring in the fishing stage, and impacts occurring in later, post-landing phases of the products life cycle. It is also important to distinguish between different types of impacts, see Fig. 1.

The figure serves to illustrate the life cycle perspective as well as the impact types, and is further elaborated in the following.

(1) Fishing activities have a direct impact on the stock of the target species. In a wider perspective the exploitation of target species may influence the non-target species and the surrounding marine ecosystem, as illustrated by the concentric circles.
(2) Apart from the direct impact on target species, fishing activities lead to impacts on non-target species such as other fish, invertebrates, marine mammals, and birds. The direct impact on non-target species may also have indirect effects on the surrounding marine ecosystem, including feedback effects on the target species.
(3) A direct impact on other parts of the marine ecosystem (e.g. the benthic ecosystem) can also be observed. One example is the use of demersal fishing gear that inflicts damage to the seafloor. Another example is the loss of fishing gear (or other types of wastes), and the release of biocides from anti-fouling[2] paint, which can have effects anywhere in the marine ecosystem [3]. This may have feedback effects on non-target and target species as well.
(4) Fishing activities also have negative impacts on parts of the external environment that do not belong to the marine ecosystem. This is mainly related to the combustion of fossil fuels and emissions of gases such as carbon dioxide (contributing to global warming), sulphur and nitrous oxides, contributing to effects such as nutrient enrichment and acidification.
(5) Impacts also occur during the post-landing product chain. This involves the processing industry, wholesale and transport processes. The environmental impacts are related to consumption of energy (with related emissions), chemicals, water and other resources as well as generation of waste and various types of emissions to air and water.
(6) Finally, the products reach the consumer. The environmental aspects related to shopping, storing, cooling, food preparation as well as disposal of packaging and leftovers involve a number of inputs and emissions.

The grey arrow emphasizes the feedback from the external environment. For instance, the greenhouse effect may change the production conditions in the marine ecosystem, which in turn may change the abundance and composition of species in a given area [10].

2.1. Different categories of eco-labels

Inspired by Chaffee et al. [11] the present article approaches the analysis of eco-labelling by distinguishing between two types of eco-labels for seafood products, namely 'single attribute' and 'multiple attribute' eco-labels. An example of a single attribute eco-label is the 'Dolphin Safe Tuna' label aimed at minimising/avoiding by-catch of dolphins. An example of a multiple attribute label is the 'MSC' eco-label (Marine Stewardship Council) that focuses on the protection of fish stocks and marine ecosystems in broader terms. It can be argued, however, that it is possible to distinguish between two subcategories of multiple attribute labels; one that mainly focuses on the fishing stage, arrows 1–3 in Fig. 1 (e.g. MSC) and another that addresses the 'environmental' impacts in the whole life cycle of the products, arrows 1–5 in Fig. 1. An example of the latter is the KRAV eco-label that will be elaborated on later in this article. Hence, there remain single attribute and multiple attribute labels of which the 'MSC approach' and the 'life cycle approach' are two subcategories. This article will therefore, discuss on the following three types of eco-labelling schemes for wild-caught seafood, namely:

- Single attribute labels such as the 'Dolphin Safe Tuna' label, which typically focus on the protection of one single species [12];
- Resource oriented multiple attribute labels that focus on sustaining the reproductive capacity of fish stocks by limiting over-fishing and adverse effects on marine ecosystem. One example is the MSC label [13];
- Multiple attribute eco-labels that focus on environmental aspects in a broader sense (not only a marine ecosystem focus) and which address environmental aspects in the whole life cycle of the product. The Swedish 'KRAV' eco-label represents an eco-label in this category [14].

The following section includes a description and analysis of eco-labels within these three categories.

3. Analysis of four different eco-labels for seafood

Based on the conceptual framework presented in the previous sections, the following contains an analysis of four different eco-labels: 1) the 'Dolphin Safe Tuna', 2) the MSC label, 3) the Swedish KRAV label for wild-caught seafood, and 4) a Danish label suggested by the Danish NGO – the Danish Society for a Living Sea (DSLS). The first two are the examples of well-known international eco-labels, while the latter two are national labelling initiatives of a much smaller scale. The KRAV eco-label has only certified four fisheries (primo 2008) and that the suggested Danish eco-label (from DSLS) hasn't been used for several years. The latter is still of interest, because it includes an approach targeted at minimizing energy consumption.

The analysis describes the labels' comprehensiveness in terms of environmental aspects and life cycle stages that are being addressed, and discusses the criteria vis-à-vis findings in LCA

[1] It should be acknowledged that the Code explicitly mentions energy consumption. It is stated that "States should promote the development of appropriate standards and guidelines which would lead to the more efficient use of energy in harvesting and post-harvest activities within the fisheries sector" [5].

[2] Anti-fouling agents are used to inhibit the growth of barnacles and other marine organisms on the hull of the fishing vessels. Anti-fouling agents typically contain tin or copper compounds [3].

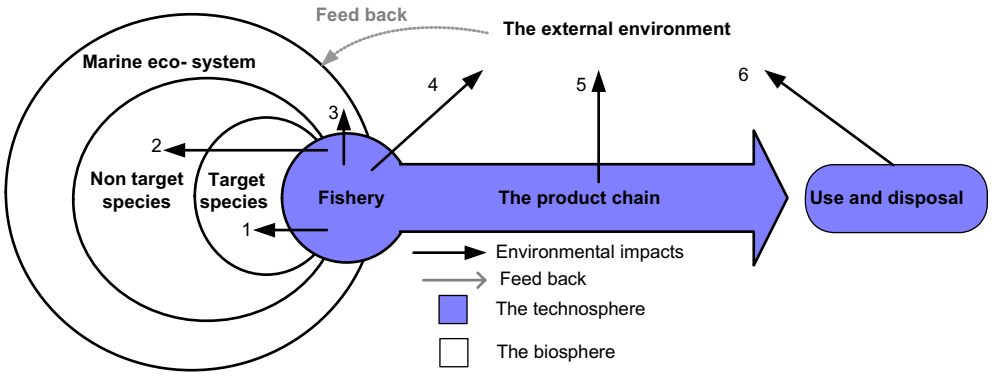

Fig. 1. Environmental impacts at different life cycle stages of seafood products [3].

studies. Most attention is given to MSC and KRAV, because both labels are currently in use (unlike DSLS) and address many types of seafood products (unlike Dolphin Safe Tune).

It should be stressed that operators of labelling schemes such as Dolphin Safe and Marine Stewardship Council (MSC) explicitly talk about managing the impacts of fishing – not managing the impacts of seafood 'products' in a 'life cycle perspective'. Hence, the analysis, critique and suggestions for improvements suggested in this article, do not imply that the operators have made any false claims or that the labels are irrelevant or ineffective.

Despite their potential importance from a sustainability perspective, social aspects have been considered beyond the scope of the present paper.

Finally, it should be mentioned that these only represent a selection of the eco-labels that exist. An overview of other eco-labels is available in Wessells et al. [6] and Phillips et al. [15]. Apart from this there exist a growing number of seafood consumer guides such as the 'Seafood Watch' prepared by the WWF and the Monterey Bay Aquarium, which are not product labels as such.

3.1. Dolphin safe tuna

The 'Dolphin safe tuna' eco-label was initially established in 1990, based on the initiatives taken by the Earth Island Institute 'International Marine Mammal Project'. The label prohibits intentional chasing, netting and encirclement of dolphins and the use of drift gillnets to catch tuna. It is also prohibited to mix dolphin safe and 'ordinary' tuna onboard the vessels and observers must be present in certain fisheries [12].

This eco-label must be characterized as a single attribute label that focuses on the unintended impacts of fishing on non-target species (arrow 2) in Fig. 1. In other words, the label addresses 'one' environmental issue (by-catch) and the criteria do not address wider ecosystem impacts, nor energy consumption or impacts in other life cycle stages.

By purchasing tuna with this label, consumers can support tuna fisheries, where adverse impacts on dolphins are minimised.

3.2. The marine stewardship council (MSC)

The MSC label is an example of a label that focuses on the protection of the marine resources, mainly the target species (arrow 1 in Fig. 1), but also by-catch and impacts on the marine ecosystem more generally (arrows 2 and 3 in Fig. 1). The Council was established by Unilever (one of the world's largest whitefish buyers) and the conservation organization WWF in 1997, and it became an independent organization in 1999 [13]. The MSC label has detailed procedures for third-party certification, accreditation, stakeholder involvement as well as announcement of all steps taken in the certification process on the MSC website with stated periods for objections. However, the environmental criteria are limited to the fishing stage [16,17].[3]

The MSC label must be characterized as a multiple attribute eco-label focused on the marine resources and the marine ecosystem. Compared to the Dolphin Safe Tuna eco-label, the MSC label applies a wider set of criteria related to the entire marine ecosystem – and even includes operational criteria which demand a minimization of operational waste such as lost fishing gear, oil spills and onboard spoilage of catch [16].

The MSC eco-label complies with the FAO guideline for eco-labelling of seafood products published in 2005 [7], which requires third party auditing and verification. The assessment process is rigorous and involves a number of phases comprising a confidential pre-assessment of suitability for full assessment, and a public full assessment applying a detailed assessment methodology. The MSC puts great effort into the openness of its processes, and this is encouraged by posting key procedural and reporting documents to their website for public comments, requiring assessors to actively solicit inputs from all stakeholders, and providing clear objections procedures if any party feel that issues have been addressed inadequately.

MSC assessments are initiated by a contract between a client or client group and an independent MSC accredited third-party certification body that puts together an assessment team comprising experts from the fields of stock assessment, environmental impacts, fisheries management and certification procedures. The team undertakes an assessment of the fishery to ascertain whether a fishery may be considered to be 'well managed and sustainable' based around the three guiding principles of this environmental standard – Principle 1: Stock exploitation; Principle 2: Ecosystem structure and function; and Principle 3: Effective management system and practices. Accordingly, team members should have knowledge about the fishery under assessment, but be independent of it [17,18].

Detailed assessment involves the construction of an assessment tree built around a set of prescribed Criteria that give direction to how each Principle might be measured. The assessment team needs to develop the Sub-Criteria and Performance Indicators that make up this tree to reflect the particular conditions and critical concerns associated with the fishery in question. The team also needs to

[3] In the MSC Principles and Criteria for Sustainable Fishing, it is mentioned that "other complementary certification programmes (e.g. ISO 14000) provide opportunities for documenting and evaluating impacts of post-landing activities related to fisheries products certified to MSC standards" and that "Constructive solutions to address these concerns through appropriate measures should be sought" [16]. However, it is also stated that the Principles and Criteria only related to marine fisheries activities up to but not beyond the point of landing [16].

determine, in advance of scoring a fishery, exactly what conditions would allow it to allocate scores of 100 (ideal), 80 (industry best practice) and 60 (threshold of acceptability) to a Performance Indicator, and to allocate weightings that will be used in computing an overall score per Principle. Thereafter, the client is required to provide the team with the information that will allow the team to score the fishery. Team members are also expected to complement this information through a programme of interviews with fishery and other stakeholder interests, plus the collection of stakeholder views and concerns relating to practice and sustainability in this particular fishery. Where concerns are raised, the team has an obligation to further explore these concerns as part of its continuing investigations [18].

The certification process can be followed by anyone by logging on to the MSC website (www.msc.org). Here details of the assessment team, the assessment tree and later the certification report are announced, and regulated time periods are given for submission of comments and for registering objections.

In September 2007, a total of 857 different MSC-labelled seafood products in 34 countries involving 25 certified fisheries, were sold. More than 7% of the world's edible wild-capture fisheries are now certified or under certification using the MSC standard [13].

Currently 32 more fisheries are undergoing assessment and the number of certified fisheries will continue to increase rapidly. The increased demand for MSC certification is partially driven by several US and UK retail chains which will only sell MSC-labelled seafood products within a couple of years [18]. The MSC has recently developed a methodology for undertaking a risk-based assessment in data deficient situations, which is currently being tested and evaluated [13,18]. This will be quite valuable for fisheries that wish to undergo an assessment but lack the necessary data which is often the case in developing countries.

When purchasing seafood with the MSC label, consumers can enhance the profitability of well-managed fisheries and thereby, promote sustainable seafood with a focus on avoiding overexploitation. The rigorous certification process and the compliance with the FAO framework for eco-labelling of seafood products suggest that it is a label with a high level of credibility.

3.3. The KRAV eco-label

The KRAV eco-label for wild-caught seafood is an example of a more recently developed multiple attribute eco-label which includes criteria related to many types of environmental aspects and for several stages of the products life cycle (arrows 1–5 in Fig. 1). The KRAV label includes criteria addressing the following issues at the fishing stage:

- Avoiding overexploitation;
- Reducing by-catch and discard (e.g. through selective fishing gear);
- Reduction of energy consumption (e.g. demands on engine/fuel type and ban on beam trawl);
- Seafloor impacts (e.g. ban on beam trawl and required detailed position reporting);
- Waste handling (e.g. not waste dumping);
- Anti-fouling agents (paint containing tin compounds are not allowed);
- Cleaning agents;
- Animal welfare (handling with least possible suffering) [14].

At the processing stage, the eco-label has criteria that address the following aspects:

- Clear environmental targets, action plans and internal environmental audits;
- Reduction of product loss internally and through demands to suppliers;
- Packaging (only recyclable);
- Additives (only certain types are permitted)[4] [14].

This is not an exhaustive list of demands, but it gives a picture of a comprehensive eco-label that addresses many types of environmental aspects in several life cycle stages.

The KRAV certification process is initiated with an application from a single fisherman or group of fishermen. KRAV has a scientific board of biologists and fisheries managers that is consulted regarding the approval of the fished stock. It is then up to the applicant to demonstrate which criteria are fulfilled to a third-party certification body, identified by KRAV. The process is transparent, the participants of the scientific board can be found on the KRAV website. The preliminary assessment is widely circulated for comments to all possible stakeholders, not only in the fishery under assessment, but also for others, more generally interested people and organizations with regulated periods to hand in any comments, objections or additions [18].

Until now (January 2008), four Norwegian and Swedish fisheries have been KRAV certified (some have also been rejected). A number of fisheries are currently undergoing assessment. The certified fisheries are the shrimp (*Pandalus borealis*) trawl fishery in the Koster-Väderö fjord, Sweden; the Skagerrak herring (*Clupea harengus*) fishery with pelagic trawls; the Northeast arctic cod (*Gadus morhua*) fishery with long-lines in northern Norway, and the Northeast arctic haddock (*Melanogrammus aeglefinus*) fishery with the same gear and in the same area. Revisions of the criteria are made on a regular basis. The next revision is planned for 2008 [18,19].

Due to the small number of certifications, it has been possible to make a brief description of each case in the following.

Shrimp: Two vessels, of which one is currently active, have been certified which deliver their catches to the seafood auction in Göteborg. A major difference to non-certified shrimp fisheries is that the trawls are equipped with a sorting grid for sorting out the fish part of the catch. Also, certain areas of the fjord are protected from trawling. This spatial regulation was achieved in collaboration between fishermen and fishery authorities. The product chain after the auction has not yet been fully certified since the shrimp currently represents a value that is too low to motivate seafood wholesalers and retailers to go through the process of a KRAV certification. The expected increase in the number of KRAV certified fisheries will probably increase incentives of wholesalers to go through the certification process in the future. The KRAV shrimps are therefore currently not separated from conventional shrimps after the seafood auction, where a slightly higher price is paid for them. The low difference in price partly explains why so few fishermen have become involved. It is anticipated that more vessels will go into the certified fishery as soon as the demand for the labelled products increases. Some indirect marketing is done by the WWF and the Swedish Food Administration recommending consumption of the KRAV labelled shrimps [18].

Herring: The KRAV certified herring has found its way to the consumer. It is processed to three different marinated herring products by one of the larger seafood companies in Sweden, using the catch of the seven KRAV certified herring trawlers. The difference between KRAV and conventionally trawled herring is minor and mostly relates to chemicals used onboard as well as fuel and engine types. This shows that the herring trawl fishery is currently being undertaken on a largely sustainable basis whether certified or not. Most supermarkets in Sweden sell the labelled herring

[4] This is mainly from a human health perspective.

products. German companies have shown interest and German eco-labelling organizations might take on the KRAV criteria for wild-caught seafood to re-certify the same fisheries with their labels. The price for KRAV certified herring is around 15% higher than conventional herring at the point of landing. Organic vinegar is several times more expensive than conventional vinegar. This, in part, explains why the consumer price of the labelled product is around 34% higher compared to the conventional version of the product [18].

Cod/haddock: Cod and haddock represent the most recent certifications (December 2007). 13 long-line fishing vessels have been approved and are currently starting to fish on the 2008 quotas. The haddock fishery is certified all year round and the cod fishery from January to April, which is to avoid catching coastal cod. The certified products are to be processed in Norway, exported to Sweden and sold to consumers through one of the larger retail chains as both fresh and frozen fish [18].

When purchasing seafood with this label, consumers can promote products that result in lower environmental impacts in a number of life cycle stages similar to non-food products with the Nordic Swan and EU eco-labels.

3.4. Labelling initiative from Danish DSLS

In Denmark, there is limited consensus whether eco-labelling of wild-caught seafood is a good idea. However, the Danish Society for a Living Sea (DSLS) developed a proposal for eco-label criteria for wild-caught seafood in 2000. It was only possible to purchase fish products with the DSLS label for a short period. The most important of the suggested criteria are listed below:

- All vessels within three nautical miles from the coast must have a pull power that does not exceed 2½ ton, and the rule holds maximum 4 ton in all areas;
- The number of gillnets must not exceed 100 nets per fisherman per day;
- It is prohibited to use bottom dragged fishing gear on rocks;
- Weight of trawl gear must not exceed 850 kg, inclusive of outer boards. Beam and bobbin trawlings are prohibited;
- The maximum rope size in Danish seine fishing must not exceed 24 mm;
- Once a year, the fishermen are obliged to make an environmental status report (green account) describing the total consumption of diesel oil, motor oil, cleaning agents and anti-fouling paint as well as catches measured in volume and value[5];
- Seafood processing industries, exporters, retailers and restaurants are committed to minimise the consumption of water and energy, to use packaging that is environmentally sound, and to avoid chemical additives in all cases [20].

The rationale for the criteria is available in a separate background document [21]. Similar to the KRAV label, the criteria represent 'life cycle thinking' and a holistic understanding of environmental problems. Emphasis is given to the manner in which the fish are caught through the promotion of passive fishing gear and limitations of pull power as well as weight of fishing gear. The argument is that passive fishing methods and light trawls, combined with an upper limit on pull power can limit the seafloor impacts (including damage to reefs) while simultaneously reducing energy consumption. It must be acknowledged, however, that the label only has been applied for a short period involving a limited group of fishermen and marketed products. Among the possible reasons for the failure are lack of resources for marketing, control and verification. The inclusion of the DSLS scheme is to allow exploration of a wider range of criteria in the present article.

3.5. Comparison of eco-labels

The criteria for the first two types of labels mainly concern exploitation of 'biotic renewable' resources at the fishing stage. The Dolphin Safe Tuna label addresses the by-catch of non-target species, while MSC has a broader focus encompassing over-exploitation of the target species, reduction of by-catch of non-target species as well as impacts on the marine ecosystem more generally.

The analysis shows that KRAV and DSLS have an even broader perspective as they address aspects such as energy consumption, and environmental impacts in other stages of the life cycle. KRAV also addresses anti-fouling agents, even though the criteria are quite soft considering the existing international ban of tin in anti-fouling agents.

The criteria from the proposed DSLS label are interesting because they have a strong focus on promoting fishing methods which are energy efficient and which are believed to cause as little damage to the seafloor as possible. Also, the DSLS label doesn't specifically address overexploitation of seafood resources. In other words, it would not ensure that the seafood comes from sustainable stocks. The latter is the responsibility of the existing fishery managers in the EU and Denmark, according to the association. The emphasis of the DSLS label is 'how' the fish are caught instead of 'how much'.

The label from KRAV and DSLS is only intended to be used in their respective countries – at least initially. It must also be acknowledged that KRAV and DSLS are in a very different league than the MSC with respect to the number of certified fisheries as well as the certification processes, which is more rigorous in the case of MSC. Hence, it could be argued that a direct comparison is indeed unjustified. However, we see the KRAV and DSLS labels as interesting initiatives that fill their function on a national level and could inspire future expansions of the scope of the MSC.

3.6. Environmental importance of the fishing stage

An important question is whether the different labels focus on the most important types of environmental impacts and the most important life cycle stages. Studies based on the life cycle assessment (LCA) in Denmark; Thrane [3] and Thrane [9], Sweden; Ziegler et al. [8] and Ziegler [22], Iceland; Eyjólfsdóttir et al. [23], Norway; Ellingsen and Aanondsen [24] and Spain; Hospido and Tyedmers [25], suggest that the fishing stage is the most important stage in terms of environmental impacts for most types of analyzed seafood products. This is mainly due to:

- High levels of energy consumption, which can amount to several litres of diesel per kg caught seafood. Energy consumption contributes to effects such as global warming, nutrient enrichment and acidification;
- The use of toxic anti-fouling agents[6] which contribute significantly to aquatic eco-toxicity;

[5] The intention of this criterion is mainly to increase the fishermen's awareness about energy consumption and other types of environmental impacts. However, it would also serve as a basis for benchmarking, and is necessary as a basis for ensuring continuous improvements over time.

[6] It should be acknowledged that not all fisheries in the world use anti-fouling paints, and that the findings in the LCA studies mainly cover European and North American fisheries.

- Effects on the fish stocks (biotic resource depletion) and other marine animals caught as by-catch;
- Effects on the seafloor from bottom tending fishing gear.

Most LCA studies focus on emissions related environmental impacts and the current methods are not well suited for assessments of depletion of fish stocks and seafloor damage. However, a qualitative LCA of Danish seafood products suggests that exploitation of the seafood resource probably represents the overall largest environmental burden [3].

As mentioned, the environmental importance of fishery is also due to the seafloor effects caused by demersal fishing gear. While there is a huge body of literature on these impacts of different fisheries in different regions, they can currently not readily be included in LCA methodology and development of standards for how to deal with them is highly needed as they are considered to be crucial environmental aspects of some fisheries. These aspects have been discussed qualitatively in some studies Eyjólfsdóttir et al. [23] and Thrane [3] and quantified in others Ellingsen and Aanondsen [24], and Ziegler et al. [8]. A study developing a methodology to assess seafloor impact for application in seafood LCAs has, however, been conducted by Nilsson and Ziegler [26], a methodology that has been applied in Ziegler and Valentinsson [27].

3.7. Environmental importance of life cycle stages after landing

The processing stage is important for some seafood products such as canned mackerel, partly due to the energy consumption for cooling, cooking and processing the seafood, but also due to the use of large amounts of aluminium cans that represent a high energy consumption. Wastewater emissions can be a cause of eutrophication in situations where effective wastewater treatment is absent, and it is always important for the processing stage to reduce the product loss to reduce the environmental impacts in the previous life cycle stages [3,22,25]. A recent review by Ziegler and Nilsson [28] confirms these findings.

The LCA studies also point towards the transportation, retail and consumer stages as important in terms of environmental impacts for most seafood products. This is mainly due to high levels of energy consumption for transport, cooling/storing and cooking.

4. Discussion

4.1. Criteria versus environmental impacts

It is common sense that the use of the resource base in wild production, in this case target and by-catch stocks, must be done on a sustainable basis in order to maintain an environmentally efficient and sustainable fishery. The importance of overexploitation of seafood resources is confirmed by the LCA studies, and it seems highly relevant to address overexploitation, especially if an eco-label, such as the MSC is intended to be applicable internationally, since regulations are absent or poorly enforced in many regions of the world. However, it should be acknowledged that fisheries in some regions (e.g. Scandinavia and EU) are already highly regulated with respect to maximum allowable catch. KRAV, MSC and DSLS have criteria related to minimizing seafloor impacts, and KRAV also addresses anti-fouling agents, which match the findings of the LCA studies. Considering the high impact potential of anti-fouling agents, it is noticeable that the other eco-labels do not address this issue.

In the rest of the life cycle, it is only KRAV and DSLS that have developed criteria. None of the labels address the retail and use stages, but this is also difficult in practice. Both labels focus on the minimization of product waste at the processing stage and generally address post-landing environmental aspects, which are highlighted as environmental hot-spots by the LCA studies.

LCA studies suggest that the energy consumption is not only highly important in the fishing stage but also in the rest of the product chain. Furthermore, we see an increasing interest for carbon footprint among politicians and consumers. This speaks for a stronger focus on energy considerations in eco-labelling criteria for seafood, in particular for MSC.

4.2. Possible handling of energy aspects

KRAV and DSLS address energy aspects by focusing on the 'input' in terms of the technology that is being used (e.g. the type of vessel, engine, fuel and fishing gear). The strength of this approach is that it is relatively simple. Also, significant improvement potentials can be realized by shifting from one fishing method to another. Studies of the Danish flatfish fishery show that a difference of a factor 15 can be observed in fuel consumption per kg of flatfish caught, depending on the fishing gear that is used, see Fig. 2. The potential improvement that can be achieved by increasing the share of more environmentally efficient types of gear was also shown by Ziegler and Hansson [29] and Thrane [30], and an assessment of the environmental performance of different fishing methods is available in Ziegler [22].[7] KRAV is currently (2008) involved in the development of qualitative criteria for carbon footprint labelling which will be an add-on label to the existing KRAV label. Criteria are to be launched and the first climate-labelled food products should arrive in the market during 2009. Seafood products are one of the groups where criteria development is currently ongoing. It is interesting to note that this is the first time food transports with regard to both transport mode and distance will be analyzed by KRAV.

Beam and bottom trawls as well as dredges are generally among the most fuel consuming fishing methods[8] and are also characterized by the considerable damage to seafloor habitats as the gear types are in contact with the bottom to some extent. It is possible that the inclusion of criteria specifying fishing methods, as suggested by KRAV and DSLS could stifle innovation and prevent the use of fishing methods that might be improved or which could be used more efficiently.

Another way of handling energy consumption would be to develop criteria related to the maximum fuel consumption. In this case, the focus is the output or the amount of fuel used per kg caught or landed fish. Fuel use is traceable and so are catches, which means that it would be possible – at least in theory. It could be implemented through a reward system where fisheries undergoing certification get a credit if it is documented that the fuel consumption per kg of landed fish is under a certain limit. Other ways of handling it could be the use of fuel quota (or carbon credits like many other industries' use) where a vessel or a group of vessels are allowed to use a certain amount of fuel within a given time period. If the energy quota was tradable, it would allow energy efficient fisheries to sell their remaining quota and get a reward this way. This 'output' approach gives an incentive to the users of inefficient gear to innovate and to reduce the fuel consumption. Still, one of the barriers could be the challenge of deciding and allocating the fuel quota between different fisheries, considering that fuel consumption depends on many variables such as the

[7] It is surprising that very fuel-efficient fishery and very fuel inefficient fisheries can exist side by side. However, it should be remembered that fuel-efficient fisheries such as Danish seine have other downsides such as relatively higher labour costs and smaller catch opportunities during winter – at least in Denmark [3,30].

[8] In Danish and Swedish fisheries targeting Norway lobster, fuel intensities of 5–8 l of diesel per kg Norway lobster caught, have been identified, which is significantly more than the energy required to produce e.g. meat products in agriculture [3,27].

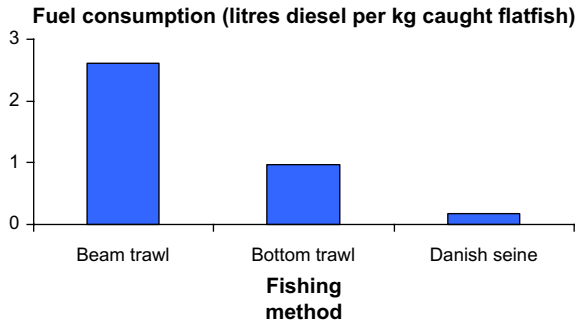

Fig. 2. Fuel consumption per kg caught flatfish in year 2000 [30].

season, the weather, the fishing ground and the condition of the fish stock.

5. Conclusions and perspectives

The analysis shows that the criteria and scope of existing and emerging eco-labels for wild-caught seafood vary considerably. Some labels address relatively few impact types at one stage of the life cycle while others address many types of impacts in several life cycle stages of the seafood products.

5.1. Eco-labels that address the fishing stage

The simplest form of eco-labels for seafood products only addresses one important issue or attribute, such as by-catch of dolphins. An example of this type of label is the 'Dolphin Safe Tuna' eco-label. This type of label is simple but sends a clear message to consumers and might be effective in addressing what is considered to be an important problem in a certain fishery.

An example of an eco-label that represents a broader understanding of sustainable fisheries is the MSC label. This label has gained significant momentum over recent years a development, which has also been driven by more environmentally conscious consumers and proactive retail chains in countries such as UK. The MSC addresses the sustainability of fisheries more generally and focuses on avoiding overexploitation, negative impacts on the marine ecosystem and sound management practices. LCA studies confirm that the fishing stage and the exploitation of seafood resources are very important (in terms of the environmental burden). The MSC addresses many highly relevant environmental aspects at the fishing stage and has rigorous certification processes, which gives the label a high level of credibility.

From a more critical stand point it must be taken into consideration that LCA studies single out energy consumption and anti-fouling agents used on the fishing vessels hull, as highly important factors contributing to impact categories such as global warming, nutrient enrichment, acidification and eco-toxicity. Some seafood products require several litres of fuel input per kg seafood product that is caught, which is significantly more than is used for other meat products in the agricultural production. So far, the MSC label has not addressed these types of issues.

5.2. Life cycle oriented eco-labels

Two of the analyzed eco-labels, KRAV and DSLS, do include criteria for energy consumption, anti-fouling agents as well as impacts from other life cycle stages after landing of the seafood. These eco-labels include criteria aimed at reducing the consumption of toxic anti-fouling agents, the use of energy, waste and certain types of packaging – not only during fishing operation, but also after landing. As an example, the KRAV eco-label requires that processing plants have implemented environmental action plans to reduce the fish waste while using more eco-friendly types of packaging, and transport.

Energy consumption has a high priority, especially in the proposed label from DSLS in Denmark, where certain fishing methods are discouraged due to their high carbon footprint per kg caught fish as well as their impacts on the seabed.

Hence, the criteria in the life cycle oriented eco-labels are to a high degree in accordance with the environmental hot-spots identified in LCA studies. It should be mentioned however, that these labels have a national scope, and are not challenged with the goal of reducing overexploitation on a global level. Furthermore the Danish initiative hasn't been used for several years. In other words, this is not a comparison of fully operational labelling schemes. That being said, it is our opinion that the national initiatives could serve as inspiration for international labelling initiatives such as MSC, which already have taken the first steps towards a holistic interpretation of sustainable fisheries. The next step is to expand the focus to include aspects such as carbon emissions and toxic emissions, and to broaden the scope from sustainable 'fisheries' to sustainable seafood 'products' in a longer time perspective. The life cycle perspective is much needed and has generally been lacking when it comes to food products, including organic agricultural products. It must be acknowledged, however, that it presents a greater challenge in terms of control and verification, which is a very important issue that has not been separately addressed on the present paper.

We suggest that energy consumption at the fishing stage could be handled by focusing on various technology factors – e.g. the fishing gear and the fishing vessel or engine type. However, the criteria could also address the actual fuel consumption per kg of seafood caught. This is a more outcome-oriented approach that could be handled through tradable fuel quotas or economic means of control such as fuel taxes.

5.3. Recommendations and reflections

Based on the experiences and results we have LCA of food and seafood products and considering the current focus on carbon footprint and life cycle thinking, it is our recommendation that established international eco-labels such as MSC should initiate a discussion of incorporating some of the additional environmental aspects that have been discussed in the present article. It is unrealistic to expand the focus to all types of environmental impacts in all life cycle stages simultaneously. However, there are some aspects such as energy consumption at the fishing stage that would be worthwhile addressing over a relatively short time horizon.

This article has not addressed the challenge of control and verification – nor has it analyzed the actual results of the various eco-labels in terms of improvements of stocks, marine ecosystem impacts or other types of impacts on the external environment.

Trust is essential when it comes to eco-labelling, and procedures which ensure the consumers that the products are produced under circumstances meeting the criteria and intentions of the eco-label are the key factors for success. The fact that the MSC eco-label complies with the FAO guidelines for eco-labelling of seafood product, gives the label a high level of credibility. It is obviously important that an expansion of the criteria to include aspects such as energy and impacts in several life cycle stages, represents a challenge in this regard. The authors acknowledge that it is pivotal not to jeopardize the credibility of a label by including many factors that subsequently cannot be verified adequately.

The actual effects that have been or will be obtained through different approaches have not been analyzed. But it is indeed possible that an eco-label such as MSC will contribute to reduce overexploitation of seafood resources globally – partly because of the direct effect of the label, but also due to the indirect effect caused by the increased attention among consumers and

politicians. It can be questioned though, whether the current version of the MSC eco-label has a significant impact in fisheries or areas where the existing fishery already works effectively [15,31,32]. The first group of Danish fishermen that underwent MSC certification is with vessels targeting pelagic fish (mainly herring and mackerel). This paper endorses the need for criteria which include aspects such as energy efficiency, which are not currently addressed by schemes such as the MSC. Apart from representing a welcome challenge for already well-managed fisheries, a focus on energy consumption would also provide a benefit for artisanal fisheries in developing countries, as they are often highly energy efficient due to the low-tech solutions that are applied [33,34].

The FAO is currently (2008) undertaking a number of pilot studies on eco-labelling of wild-caught seafood products in developing countries as is the MSC with their risk-based assessment methodology for data deficient situations, as mentioned above. In parallel, the FAO has also commissioned an LCA of an artisanal shrimp fishery in Senegal, which is the first LCA study to be done of a small-scale fishery in a developing country. All of these recent developments on various levels are very promising for those interested in reaching increased sustainability in the world's seafood production from capture fisheries.

References

[1] FAO. The state of world fisheries and aquaculture 2006. Rome: Food and Agriculture Organization of the United Nations (FAO), Fisheries Department; 2007.
[2] European Commission. Green paper – the future of the common fisheries policy. Bruxelles: European Commission; 2001.
[3] Thrane M. Environmental impacts from Danish fish products. PhD dissertation. Aalborg University, Department of Development and Planning, Aalborg, Denmark; 2004.
[4] Steneck RS, Carlton JT. Human alterations of marine communities. In: Bertness MD, editor. Marine community ecology. Sunderland, Massachusetts: Sinauer Associates; 2001 [chapter 17].
[5] Food and Agriculture Organization of the United Nations (FAO). Code of conduct for responsible fisheries. FAO; 1995.
[6] Wessells CR, Cochrane K, Deere C, Wallis P, Willmann R. Product certification and ecolabelling for fisheries sustainability. FAO fisheries technical paper no. 422. Rome, FAO; 2001.
[7] Food and Agriculture Organization of the United Nations (FAO). Guidelines for the ecolabelling of fish and fishery products from marine capture fisheries. Adopted by the twenty-sixth session of the committee on fisheries (COFI). Rome; 7–11 March 2005.
[8] Ziegler F, Nilsson P, Mattsson B, Walther Y. Life cycle assessment of frozen cod fillets including fishery-specific environmental impacts. International Journal of Life Cycle Assessment 2003;8(1):39–47.
[9] Thrane M. Environmental impacts from Danish fish products – new methods and insights. International Journal of Life Cycle Assessment 2006;11(1):66–74.
[10] Hall SJ. The effects of fishing on marine ecosystems and communities. The Flinders University of South Australia. London: Blackwell science; 1997.
[11] Chaffee C, Leadbitter D, Aalders E. Seafood evaluation, certification and consumer information. In: Phillips B, Ward T, Chaffee C, editors. Eco-labelling in fisheries: what is it all about? Oxford: Blackwell Science; 2004.
[12] Earth Island Institute, International 'Dolphin Safe' standards for tuna. The Earth Island Institute, The International Marine Mammal Project. http://www.earthisland.org/immp/ [accessed January 2008].
[13] MSC. About MSC. The Marine Stewardship Council. London. http://www.msc.org/html/content_462.htm [accessed January 2008].
[14] KRAV, Regler för KRAV-certificered production – utgåva January 2008. KRAV ekonomisk förening. Uppsala, Sweden.
[15] Phillips B, Ward T, Chaffee C, editors. Eco-labelling in fisheries: what is it all about? Oxford: Blackwell Science; 2004.
[16] MSC. MSC Principles and criteria for sustainable fishing. The Marine Stewardship Council. London. http://www.msc.org/assets/docs/fishery_certification/MSCPrinciples&Criteria.doc [accessed January 2007].
[17] May B, Leadbitter D, Sutton M, Weber M. The Marine Stewardship Council (MSC) – background, rationale and challenges. In: Phillips B, Ward T, Chaffee C, editors. Eco-labelling in fisheries: what is it all about? Oxford: Blackwell Science; 2003.
[18] Interview with Marc Wester responsible for eco-labelling of seafood products at KRAV. KRAV ekonomisk förening, Uppsala; January 14th.
[19] KRAV. Certifieringar av fiske. http://www.krav.se/sv/Foretag/Certifieringar/Fiske/ [accessed January 2008].
[20] Danish Society for a Living Sea (DSLS). Levendehav. Regler for økologisk fiskeri [Criteria for organic fisheries]. http://www.levendehav.dk/politik/oekoligiske_fisk/regler-for-fiskeri.htm. Criteria were developed in 2000. [Homepage accessed April 2006].
[21] Danish Society for a Living Sea (DSLS). Bemærkninger til regler for økologisk fiskeri [Comments to criteria for organic fisheries]. http://www.levendehav.dk/politik/oekoligiske_fisk/bemaerkninger.htm. Criteria were developed in 2000. [Homepage accessed April 2006].
[22] Ziegler F. Environmental life cycle assessment of seafood products from capture fisheries. Doctoral thesis. Department of Marine Ecology, Sweden: Göteborg University; 2006.
[23] Eyjólfsdóttir HR, Yngvadóttir E, Jónsdóttir H, Skúladóttir B. Environmental effects of fish on the consumer's dish – life cycle assessment of icelandic frozen cod products. Reykjavik Island: Icelandic Fisheries Laboratories (IFL); 2003.
[24] Ellingsen H, Aanondsen SA. Environmental impacts of wild caught cod and farmed salmon – a comparison with chicken (7 pp). International Journal of Life Cycle Assessment 2006;11(1):60–5.
[25] Hospido A, Tyedmers P. Life cycle environmental impacts of Spanish tuna fisheries. Fisheries Research 2005;76:174–86.
[26] Nilsson P, Ziegler F. Spatial distribution of fishing effort in relation to seafloor habitats of the Kattegat, a GIS analysis. Aquatic Conservation: Marine and Freshwater Ecosystems 2006;17:421–40.
[27] Ziegler F, Valentinsson D. Environmental life cycle assessment of Norway lobster (*Nephrops norvegicus*) caught along the Swedish west coast by creels and conventional trawls. Int J Life Cycle Assess 2008;13:487–97.
[28] Ziegler F and Nilsson P (manuscript). Environmental life cycle assessment: a new perspective on resource use and environmental impact of fisheries.
[29] Ziegler F, Hansson PA. Emissions from fuel combustion in Swedish cod fishery. Journal of Cleaner Production 2003;11:303–14.
[30] Thrane M. Energy consumption in the Danish fishery – identification of key factors. Journal of Industrial Ecology 2004;8:223–39.
[31] Kuntzsch V. Is eco-labelling working? Part A: an overview. In: Phillips B, Ward T, Chaffee, editors. Eco-labelling in fisheries: what is it all about? Oxford: Blackwell Science; 2004.
[32] Leadbitter D. Is the MSC making a difference to fisheries management? The future of eco-labelling in Australia. Conference paper. Australia; 2003.
[33] Interview with Christian Olesen, Director for Danmarks Pelagiske Producentorganisation [The Danish Pelagic Producer organization]. Hirtshals; January 10th 2008.
[34] Food and Agriculture Organization of the United Nations (FAO), Fisheries and Aquaculture Department. Small-scale and artisanal fisheries. http://www.fao.org/fishery/topic/14753 [accessed January 2008].