

# Monterey Bay Aquarium Seafood Watch®

## Seafood Watch® DRAFT Energy (GHG Emissions) Criteria for Fisheries and Aquaculture

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# Monterey Bay Aquarium Seafood Watch®

## Seafood Watch® DRAFT Energy (GHG Emissions) Criteria for Fisheries and Aquaculture

### Public comment period – 1

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#### Introduction

The Monterey Bay Aquarium is requesting and providing an opportunity to offer feedback on the Seafood Watch Energy (Greenhouse Gas (GHG) Emissions) Assessment Criteria for Fisheries and Aquaculture during our current revision process. Before beginning this review, please familiarize yourself with all the documents available on our [Standard review website](#).

## Providing feedback, comments and suggestion

This document contains the draft version of the Energy (GHG Emissions) Criteria for Fisheries and Aquaculture. These new criteria are under development with the emphasis of future work on refining both criteria. In their current form, these criteria are companions to the Fisheries and Aquaculture Assessment Criteria and are unscored due to data limitations. Seafood Watch will use these criteria to stimulate data collection and may score them in the future. "Guidance for public comment" sections have been inserted and highlighted, and various general and specific questions have been asked throughout. Seafood Watch welcomes feedback and particularly suggestions for improvement on any aspect of the Energy (GHG Emissions) Criteria. Please provide feedback, supported by references wherever possible in any sections of the criteria of relevance to your expertise.

## Seafood Watch DRAFT Energy Criteria for Fisheries and Aquaculture

**Public comment guidance** - This section contains the draft guiding principle for the Energy (GHG Emissions) Criteria, and we welcome suggestions for improvements.

**Comment:** Add the term "climate change," as in "...sea temperatures, and accelerates climate change."

### *Guiding Principle*

The accumulation of greenhouse gases in the earth's atmosphere and water drives ocean acidification, contributes to sea level rise and affects air and sea temperatures. Sustainable fisheries and aquaculture operations will have low greenhouse gas emissions compared to land-based protein production methods.

**Public comment guidance** - This section contains the draft rationale and summary for the Energy (GHG Emissions) Criteria for both fisheries and aquaculture.

Specific feedback requests:

Please comment on the appropriateness of classifying GHG emissions related to fisheries and aquaculture seafood production relative to GHG emissions from land-based protein production. Furthermore, is it appropriate to classify those products with lower emissions than poultry production as low emission, those between poultry and beef production as moderate emission and those higher than beef production as high emission? Do you have an alternative suggestion for quantifying and/or scaling the GHG emissions of fisheries and aquaculture?

### **Comment**

**Look at the FAO's comments on emissions from marine industry. This is important to include, even if unscored.**

## Rationale for and Summary of the Energy Criterion for Fisheries and Aquaculture

Seafood Watch is proposing the incorporation of GHG emission intensity into our science-based methodology for assessing the sustainability of both wild caught and farmed seafood products. GHG accumulation in the Earth's atmosphere and water drives ocean acidification, contributes to sea level rise and affects air and sea temperatures. The proposed criterion will evaluate greenhouse gas emissions per edible unit of protein from fisheries and aquaculture operations up to the dock or farm gate (i.e. the point of landing), consistent with the scope Seafood Watch assessments.<sup>1,2</sup> Although a reliable index to define sustainable (or unsustainable) emissions of GHGs does not yet exist, as a baseline, we expect sustainable fisheries and aquaculture operations to have relatively low GHG emissions compared to the demonstrably high emission of some land-based protein production methods. Therefore, in order to classify the GHG emission intensity of seafood products, Seafood Watch initially proposes to relate them to those of intensive poultry and beef production; with products falling below poultry production considered as low emission sources, those between poultry and beef as moderate emission sources, and those above beef as high emission sources.

For the wild-capture fisheries criterion, Seafood Watch proposes using Fuel Use Intensity (FUI) to derive GHG emissions intensity. For the aquaculture criterion, we propose a measure of direct farm-level GHG emissions use plus an indirect measure of the GHG emissions associated with feed production. The direct farm-level GHG emissions will be based on the energy used in water pumping and aeration (also factoring in the use of renewable energy sources). Emissions associated with feed will be based on the dominant feed-ingredient categories (aquatic, crop and land animal), and values will be sourced from existing data. GHG emission intensity per edible unit of protein for both fishery and aquaculture products will be calculated using species-specific edible protein estimates based on a literature review.

Commercial fisheries and fish farms can achieve both environmental and financial benefits from reducing their energy use. We recognize, however, that data collection related to energy use and availability is currently limited, so our aim with this criterion is to incentivize the collection and provision of energy use data to both track and improve the sustainability of seafood products.

In this first iteration, the Seafood Watch Energy Criterion will be an unscored addition to the Seafood Watch criteria, and will be used as a companion criterion to our sustainable fisheries and aquaculture assessments.

### Wild Capture Fisheries Energy Criterion

**Public comment guidance - This section contains the introduction to the Fisheries Energy (GHG**

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<sup>1</sup> Seafood Watch assesses the ecological impacts on marine and freshwater ecosystems of fisheries and aquaculture operations up to the dock or farm gate. Seafood Watch assessments do not consider all ecological impacts (e.g. land use, air pollution), post-harvest impacts such as processing or transportation, or non-ecological impacts such as social issues, human health or animal welfare.

<sup>2</sup> In the future, Seafood Watch also plans to develop a post-harvest greenhouse gas emissions calculator (outside the scope of the current standards review).

Emissions) Criterion. Feedback on the methodology is requested in the Methods section. We are not requesting specific feedback on this section, but feel free to comment on this general background information.

**Comment**

## Introduction

Fuel consumption is the primary driver of greenhouse gas (GHG) emissions up to the point of landing for most wild capture fisheries, and is often the main source of emissions through the entire seafood supply chain. As such, measures of fuel consumption in fisheries provide an effective proxy for assessing the GHG emissions, or carbon footprint, of fishery-derived seafood products.

Fuel consumption varies significantly between fisheries targeting different species, employing different gears, and operating in different locales. Fuel use also varies within fisheries over time: consumption increased in many fisheries throughout the 1990s and early 2000s, but has reversed in recent years as fisheries in Europe and Australia have both demonstrated consistent improvement in fuel consumption coinciding with increased fuel costs since 2004. As a result of this variation in fuel use, while it is difficult to estimate fuel consumption of individual fisheries without measuring it directly, generalizations can be made by analyzing previously reported rates in fisheries with similar characteristics. To this end, Robert Parker (PhD Candidate, Institute for Marine and Antarctic Studies, University of Tasmania, Australia) and Dr. Peter Tyedmers (Dalhousie University, Nova Scotia, Canada) manage a database of primary and secondary analyses of fuel use in fisheries (FEUD – Fisheries and Energy Use Database). Using this database, the draft Seafood Watch wild capture energy criterion is based on “Fuel Use Intensity” (FUI, as liters of fuel consumed per metric ton of round weight landings, L/MT) converted to Green-House Gas Emission Intensity per edible unit of protein (KgCO<sub>2</sub> equivalent/Kg edible protein).

**Public comment guidance** - This section contains the methodology for the Fisheries Energy (GHG Emissions) Criterion. General feedback is welcome, and we ask for the following specific feedback.

Specific feedback requests:

Please provide suggestions for how best to obtain fuel use (and fuel type) data directly from the fisheries Seafood Watch assesses. Currently, we rely on data from Peter Tyedmers and Robert Parker’s Fisheries and Energy Use Database.

Please provide information/suggestions for a standardized method to incorporate GHG emissions associated with bait use for those fisheries that require bait.

**Comment: Difficult. Perhaps a proxy scale could be created, such as typical distance from shoreline. U.S. companies may report fuel expenses in annual reports or other documents.**

## Methods

### *Determining Greenhouse Emission Intensity from Fuel Use Intensity*

Fisheries were categorized by species, ISSCAAP (International Standard Statistical Classification of Aquatic Animals and Plants) species class, gear type and FAO area. These codes were used to match each fishery to a subset of records in the FEUD database<sup>3</sup> and each subset was analyzed using R to provide descriptive statistics and a weighted FUI estimate.

The subset of database records used to estimate FUI of each fishery was selected using a ranked set of matching criteria. The best possible match in each case was used. The following ranking of matches were used to choose the subset most appropriate for each fishery's estimate:

- 1) Records with matching individual species, gear type and FAO area
- 2) Records with matching individual species and gear type
- 3) Records with matching species class (ISSCAAP code), gear type and FAO area
- 4) Records with matching species class (ISSCAAP code) and gear type
- 5) Records with matching generalized species class (set of ISSCAAP codes), gear type and FAO area
- 6) Records with matching generalized species class (set of ISSCAAP codes) and gear type

For each fishery, after selecting the most appropriate subset of records, the following information was calculated:

- weighted mean (see below)
- unweighted mean
- standard deviation
- standard error
- median
- minimum value
- maximum value
- number of data points
- number of vessels or observations embedded in data points
- temporal range of data

The weighted mean, intended as the best possible estimate of FUI for each fishery, was calculated and weighted by both number of vessels in each data point and age of the data. The log of the number of vessels in each data point was used, to avoid giving dominance to data points with large numbers of vessels reporting. For example, the weights of two data points representing 1000 and 10 vessels, respectively, have a ratio of 3:1, rather than 100:1. In addition, data from more recent years are given greater weight (10% difference in weight between subsequent years).

$$w_i = \log_{10}(v_i + 1) \cdot 0.9^{2014-y_i}$$

$$FUI = \frac{\sum_{i=1}^n w_i}{\sum_{i=1}^n w_i}$$

$w_i$  = the weight given to data point  $i$

$v_i$  = the number of vessels reporting in data point  $i$

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<sup>3</sup> FEUD currently includes 1,622 data points, covering a wide range of species, gears and regions. The best represented fisheries are those in Europe, those targeting cods and other coastal finfish, and those using bottom trawl gear. Coverage of fisheries from developing countries is limited but increasing. The database focuses on marine fisheries, and includes very few records related to freshwater fishes (except diadromous and catadromous species which are fished primarily in marine environments), marine mammals, or plants.

$y_i$  = the fishing year of data point  $i$   
 $n$  = sample size (number of data points included)

The weighted FUI means (L/t) were converted to GHG emission intensity (KgCO<sub>2</sub> equivalent/Kg edible protein) using a conversion factor of 3.12 kg CO<sub>2</sub> emitted per liter of fuel combusted and species specific percent yield and protein content of fish and invertebrate species. The GHG emission factor is based on an assumed fuel mix of bunker C, intermediate fuel oil, and marine diesel oil, and includes emissions from both burning the fuel and all upstream activities (mining, processing and transporting). This conversion factor was calculated using IPCC 2007 GHG intensity factors and EcolInvent 2.0 life cycle inventory database (Parker *et al.* 2014). The species specific percent yield and protein content of muscle data used to convert landed tonnage to edible protein were derived from Peter Tyedmers unpublished database of published and grey literature values.

## Quality indicators

The amount of data available pertaining to different species and gears varies dramatically, with some classes of fisheries being researched far more than others. As a result, the “quality” of FUI predictions varies. For example, Atlantic cod (*Gadus morhua*) fisheries have been researched extensively, and so FUI estimates for Atlantic cod are relatively reliable. Meanwhile, some fisheries have not been assessed, and so these estimates are based on other similar fisheries instead. Each FUI estimate generated here was given three quality ratings:

- a **match quality** indicator, reflecting the degree to which records in the database matched the species, gear and region criteria for each fishery. The species match is particularly reflected here, as all estimates match the gear type. *Low* = records match the generalized species class (e.g. crustaceans, molluscs); *medium* = records match the species class (e.g. lobsters); *high* = records match the individual species (e.g. Atlantic cod); *very high* = records match the individual species, gear type and region (e.g. Atlantic cod caught using longlines in FAO area 27). Table 2 shows a breakdown of assessed fisheries on the basis of the match quality.

**Table 2.** Criteria used to match Seafood Watch fisheries with FEUD records.

Matching factors	Number of FUI estimates
Individual species, gear type and FAO area	21
Individual species and gear type	15
Species class (ISSCAAP code), gear type and FAO area	64
Species class (ISSCAAP code) and gear type	54
Generalized species class (set of ISSCAAP codes), gear type and FAO area	45
Generalized species class (set of ISSCAAP codes) and gear type	38

- a **temporal quality** indicator, reflecting the proportion of data points from years since 2000. *Very low* = all records are from before 2000; *low* = <25% of records are from 2000 on; *medium* = 25-49% of records are from 2000 on; *high* = 50-74% of records are from 2000 on; *very high* = 75% or more of records are from 2000 on.
- a **subjective quality** indicator reflects the confidence of the author in each estimate, based on the match criteria, temporal range, variability in the data, sample size, types of sources, and general understanding of typical patterns in FUI.

The subjective quality indicator is suggested to be a good indication of the relative reliability of each estimate. It takes into account the range of data used, the method of weighting, and the degree to which the estimate reflects previous assessments of FUI in fisheries around the world. There are instances where the subjective quality indicator does not agree with the other quality rankings. For example, some estimates include a large number of older data points, and are therefore given a low temporal quality rating, but because the weighting method used gives more influence to more recent data points, the estimate closely reflects recent findings and is therefore given a high rating.

## Methods of communicating scores

Any method of communicating a score based on the FUI estimates generated here should take into account three things:

- a) the estimates are based on fuel inputs to fisheries only, and, while fuel often accounts for the majority of life cycle carbon emissions, they need to be viewed in the context of the total supply chain. Most importantly, products that are associated with a high amount of product waste and loss during processing, or that are transported via air freight, are likely to have high sources of emissions beyond fuel consumption.
- b) the quality of estimates varies, as is reflected in the quality indicators provided. Scoring fisheries with better quality estimates is easier than scoring predicted FUI of fisheries based on similar fisheries. For that reason, it may be justifiable to score only fisheries with a 'high' quality estimate, or to indicate that some scores are based on expected FUI rather than actual reported values.
- c) the score should be relative to some base value, reflecting relative performance of similar fisheries and/or alternative fishery products and/or alternative protein sources.

Seafood Watch proposes to communicate energy use in fisheries using comparative values for unprocessed meat products that would likely be an alternative to fish. The carbon footprint of unprocessed, pre-transport chicken is equal to that of unprocessed, pre-transport fish with a FUI of ~630 L/t. So a relative score based on this would show which fish products would be likely to have a lower or higher carbon footprint than chicken; values equating to the unprocessed pre-transport carbon footprint of pork, beef, etc., can also be used. The advantage of this method is that it provides consumers with the most information concerning relative impacts of food choices, beyond just seafood. Currently Seafood Watch does not have a scalar metric (as we do for the scored criteria) to score the fisheries energy criterion.

## Aquaculture Energy Criterion

**Public comment guidance** - This section contains the introduction to the Aquaculture Energy (GHG Emissions) Criterion. Feedback on the methodology is requested in the Methods section. We are not requesting specific feedback on the introduction, but feel free to comment on this general background information.

**Comment: It would be helpful to use a greater variety of peer-reviewed sources.**

### Introduction

Feed production and on-site farm energy use have been found to be the two major drivers of GHG emissions from aquaculture operations up to the farm gate. Feed production is often the greater of these two drivers, particularly for net-pen systems where important processes such as water exchange, aeration and temperature regulation are provided naturally by the ecosystem. In pond production systems, large variations in the rate of water exchange (i.e. the volume of pumping) and aeration practices mean that farm-level energy use varies greatly between species and regions. Farm-level energy use is often the primary driver of GHG emissions for tank-based recirculating systems which require energy to run all life support and control systems (Parker 2012b) (Samuel-Fitwi *et al.* 2013).

Farm location may also be a significant factor influencing total GHG emissions from aquaculture operations due differences in the regional mix of energy sources used to generate electricity. Farms that are run primarily on fossil fuel based electricity (such as coal or oil) will have much higher total GHG emissions than those run on renewable energy sources (such as hydropower, wind, geothermal or solar) or on nuclear energy (Parker 2012b).

Seafood Watch recognizes that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations. Seafood Watch also recognizes that improving practices for some of the Aquaculture Assessment Criteria may lead to more energy intensive production systems (e.g. where recommendations are better for energy-intensive closed recirculation systems than for open systems).

**Public comment guidance** - This section contains the methodology for the Aquaculture Energy (GHG Emissions) Criterion. This criterion is less well developed than the fisheries criterion, namely due the greater complexity of assessing the GHG emissions of aquaculture operations, and the very limited data available. General feedback on the development of this criterion is welcome, and we ask for the following specific feedback.

Specific feedback requests:

Please provide comments on whether the two categories (GHG emissions from feed and GHG emissions from farm-level processes) are comprehensive for quantifying the overall emissions from aquaculture operations.

Please provide information/suggestions for what additional farm-level processes should be included in the GHG emission calculation. Currently, we propose to include GHG emissions from water pumping and aeration.

**Comment**

## Methods

Seafood Watch is currently developing the methodology for assessing GHG emissions from aquaculture operations up to the farm gate. This methodology will include an assessment of the cumulative GHG emissions from feed use (primarily feed ingredient production, processing and potentially transport) as well as farm-level emissions from energy use.

We propose basing the feed component on GHG emission estimates of dominant feed ingredient groups; i.e. land animal, crop and aquatic (fishmeal and oil)(from Pelletier *et al.* 2009) along with corresponding estimates of feed types and quantities fed by operations under assessment. Where the specific origins of feed ingredients can be identified, it may be possible to determine the GHG emissions with greater accuracy.

For the farm-level component, Seafood Watch proposes quantifying GHG emissions associated with pumping, aeration and other energy consumptive activities. Seafood Watch will draw data from existing studies and data gathered directly from aquaculture operations. When data are not available to finely estimate GHG emissions for each component (feed and farm-level energy), Seafood Watch proposes defaulting to GHG estimates based on the most closely related species type, production type and the energy mix most commonly used in the region under assessment.

As with the Fisheries criterion, all emissions estimates will be standardized to GHG Intensity per edible unit of protein (KgCO<sub>2</sub> equivalent/Kg edible protein).

The total GHG emissions will be obtained by summing the GHG emissions from feed ingredients (Part 1 below) and farm-level energy use (Part 2 below).

### Part 1: GHG Emissions associated with feed ingredients/ Energy Return on Investments

For this component we propose to quantify the GHG Intensity (KgCO<sub>2</sub> equivalent/Kg edible protein) of feed ingredients, based on data from Pelletier *et al.* 2009 and methodology based on Pelletier *et al.* 2010. Where possible, Seafood Watch will determine the specific feed ingredient mix used on farms in the assessment region. Factored into this calculation is the Economic Feed Conversion Ratio (FCR), the total amount of feed used to produce a given output of animal protein, taking into account loss of feed via escapes, death, predation, disease, environmental disasters and other losses.

GHG Emissions for Feed Ingredient Inputs:

- a) Aquatic ingredient inclusion rate = \_\_\_\_\_ %
- b) Crop ingredient inclusion rate = \_\_\_\_\_ %
- c) Land animal ingredient inclusion rate = \_\_\_\_\_ %
- d) Economic Feed Conversion Ratio (FCR) = \_\_\_\_\_

Total feed cumulative GHG emissions= [(a x aquatic ingredient GHG emission mean) + (b x crop ingredient GHG emission mean) + (c x land animal ingredient GHG emission mean)] x (d/100)

Note - the mean GHG emissions for the three ingredient groups (aquatic, crop and land-animal) have not yet been defined, but will be approximated from Pelletier *et al.* 2009 and other literature.

Total feed cumulative GHG emissions (expressing edible return on investment) = \_\_\_\_\_ Kg CO<sub>2</sub> equivalents/Kg of edible protein

Kgs of edible protein (above) will be derived from metric tons of harvested fish using two factors, the species specific edible percentage and the species specific protein percentage of muscle tissue. These percentages will be drawn from Peter Tyedmers' unpublished database.

## Part 2: Farm-Level Energy Use

For this component Seafood Watch proposes to quantify the GHG emissions associated with direct farm-level energy use. The primary energy consumptive farm activities are water pumping and aeration but also might include activities such as temperature regulation. We propose the following assessment methods, depending on data availability.

### *Farm-level data*

As the most accurate measure, Seafood Watch aims to obtain farm-level information on total energy use as well as the energy mix (e.g. diesel versus electricity, but also the regional mix of fuels used for electricity generation) specific to the aquaculture operations under assessment in order to estimate farm-level GHG emissions. As with the feed component, GHG emissions will be standardized to the Kgs of edible protein.

### *Energy use values from scientific and grey Literature*

Where farm-level information is not available, Seafood Watch proposes to model GHG emissions based on production method, species and farm-level energy use data published in peer reviewed journals and available from grey literature. To estimate GHG emissions, this farm-level energy use data will be synthesized with data on the most common mix of fuels used for electricity generation in the region of assessment. As with the feed component, GHG emissions will be standardized to the Kgs of edible protein.

### *Relative energy use from water pumping and aeration*

When farm-level or literature data are unavailable, Seafood Watch has developed the following tables to classify energy use from water pumping and aeration on a relative scale, which can be translated to relative GHG emission intensity:

### **Water Pumping**

A crude estimated measure of the energy used in pumping water

Use pumping data or descriptions to select score value from the table below.

	<b>Water pumping characteristics<sup>4</sup></b>	<b>Score</b>
Zero	No significant water pumping, e.g. cages, passive fill ponds, gravity fed tanks/ponds/raceways.	5
Low	Static ponds	4
Low-Moderate	Harvest discharge or occasional exchange	3

<sup>4</sup> As a guide, Low = <1000 m<sup>3</sup>/MT, Low-Moderate = 1000 – 5,000 m<sup>3</sup>/MT, Moderate = 5,000 – 20,000 m<sup>3</sup>/MT, Moderate-High = 20,000-150,000 m<sup>3</sup>/MT, High = >150,000 m<sup>3</sup>/MT

Moderate	Low daily exchange rate >0 to 3%	2
Moderate-High	Significant daily water exchanges 3-10%	1
High	Large daily water exchanges, recirculation systems >10%	0

Note - low energy use is given a high score

Energy use (pumping) score = \_\_\_\_\_ (range 0-5)

Record water pumping data here if available:

Pumped volume per metric ton of product \_\_\_\_\_ m<sup>3</sup> MT<sup>-1</sup>]

Average pumping head height \_\_\_\_\_ m

Average pump power \_\_\_\_\_ KW or HP

### Aeration

A crude estimated measure of the energy used for aeration

	Aeration characteristics <sup>5</sup> or average duration	Score
Zero	Zero	5
Low	Minimal aeration	4
Low-Moderate	Low power and/or short duration <6h/day	3
Moderate	Moderate power and/or 6-12h/day	2
Moderate-High	Moderate-high power and/or 12-18h/day	1
High	High power and/or >18 hours per day	0

Note low energy use is given a high score

Energy use (aeration) score = \_\_\_\_\_ (range 1-5)

Record aeration data here if available:

Aeration energy use = \_\_\_\_\_ kW·h per MT

Average aeration duration per day \_\_\_\_\_

Aerator power \_\_\_\_\_ kWh or HP

### Overall Farm-level Calculations

Farm Energy Use (FEU) = Pumping + aeration

Farm Energy Use Score (FEU) = \_\_\_\_\_ (range 0-10)

If the above method is used, Seafood Watch will determine a conversion to GHG emissions in order to combine this measure with the feed GHG measure.

<sup>5</sup> As a guide, low = <500 kW·h per MT, Low-Moderate = 500 – 1,500 kW·h per MT, Moderate = 1,500-3,000 kW·h per MT, Moderate-High = 3,000 – 4,500 kW·h per MT, High = >4,500 kW·h per MT (values are for example only (based on Boyd et al, 2007) and need refining)

## References

- Nijdam, D., Rood, T. & H. Westhoek. (2012). The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes. *Food Policy* 37, 760-770.
- Parker, R. (2012). Energy use and wild-caught commercial fisheries: Reasoning, feasibility and options for including energy use as an indicator in fisheries assessments by Seafood Watch. Report for Seafood Watch, Monterey, California.
- Parker, R. (2012b). Review of life cycle assessment research on products derived from fisheries and aquaculture. Report for the Sea Fish Industry Authority, Edinburgh, UK.
- Parker, R. (2014). Estimating the fuel consumption of fisheries assessed by Seafood Watch. Report for Seafood Watch, Monterey, California.
- Parker, R., & P. Tyedmers. (2014). Fuel consumption of global fishing fleets: Current understanding and knowledge gaps. *Fish and Fisheries*.
- Parker, R, Vázquez-Rowe, I. & P. Tyedmers. (2014). Fuel performance and carbon footprint of the global purse seine tuna fleet. *Journal of Cleaner Production*.
- Pelletier, N., Tyedmers, P., Sonesson, U., Scholz, A., Ziegler, F., Flysjo, A., Kruse, A. Cancino, B. & H. Silverman. (2009). Not All Salmon Are Created Equal: Life Cycle Assessment (LCA) of Global Salmon Farming Systems. *Environmental Science and Technology* 43: 8730–8736.
- Pelletier N., & P. Tyedmers. (2010). Life cycle assessment of frozen tilapia fillets from Indonesian lake-based and pond-based intensive aquaculture systems. *Journal of Industrial Ecology* 14: 467–481.
- Samuel-Fitwia, B., Nagela F., Meyera S., Schroedera, J.P. & C. Schulz. 2013. Comparative life cycle assessment (LCA) of raising rainbow trout (*Oncorhynchus mykiss*) in different production systems. *Aquacultural Engineering* 54: 84-92.
- Tyedmers, P., Watson, R., & Pauly, D. (2005). Fueling global fishing fleets. *Ambio*, 34(8), 635-638.