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REVIEW

Eco-certification of Farmed Seafood: Will it Make a Difference?

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Abstract Eco-certification is widely considered a tool for reducing environmental impacts of aquaculture, but what are the likely environmental outcomes for the world's fastest growing animal-food production sector? This article analyzes a number of eco-certification schemes based on species choice, anticipated share of the global seafood market, size of eligible producers, and targeted environmental impacts. The potential of eco-certification to reduce the negative environmental impacts of aquaculture at scale presently appears uncertain as: (a) certification schemes currently focus on species predominantly consumed in the EU and US, with limited coverage of Asian markets; (b) the share of certified products in the market as currently projected is too low; (c) there is an inequitable and non-uniform applicability of certification across the sector; (d) mechanisms or incentives for improvement among the worst performers are lacking; and (e) there is incomplete coverage of environmental impacts, with biophysical sustainability and ecosystem perspectives generally lacking.

Keywords Eco-certification · Aquaculture · Seafood · LCA · Sustainability · Environmental impacts

INTRODUCTION

A Growing Appetite for Seafood

Seafood[1] is among the most internationally traded food commodities and constitutes 15 % of average animal protein intake for 4.3 thousand million people worldwide (FAO 2012a). The world population is expected to reach nine thousand million people around 2050 (Godfray et al. 2010), and the global middle class is growing rapidly. Increased incomes in developing countries and rapid urbanization are main drivers of an increased demand for animal source proteins, including fish and shellfish (Hall et al. 2011). The Asia–Pacific region, a major consumer and already producing 90 % of farmed seafood, is predicted to house 66 % of the world's middle class by 2030, compared to 28 % in 2010 (Kharas 2010). Asia has experienced an average increase in demand for animal source foods of 2.5–5 % per year, and the region is characterized by high fish consumption per capita (Fig. 1), now accounting for about two-thirds of global seafood consumption (FAO 2010a, 2012a, b). A growing middle class with a large appetite for seafood together with accelerated urbanization will likely amplify seafood consumption in Asia in years to come. Further potential drivers for an increased demand for fish and fishery products is the perceived health benefit from eating seafood rich in omega-3 fatty acids (Pieniak et al. 2010), and perhaps an increasing awareness of micronutrient values associated with seafood consumption (Kawarazuka and Béné 2010). From an environmental impact and resource use perspective, aquaculture has a general comparative advantage to many terrestrial animal production systems (Bartley et al. 2007; Hall et al. 2011), a fact that may further increase seafood production and consumption.

The Rise of Aquaculture

As supply from capture fisheries is stagnant or declining, aquaculture is expected to play an increasingly important role in the future global supply of seafood products (Hall et al. 2011; FAO 2012a). Aquaculture is the fastest growing sector of animal-food production in the world and

[1] In this article, "seafood" refers to all edible aquatic animals from both marine and freshwater environments.

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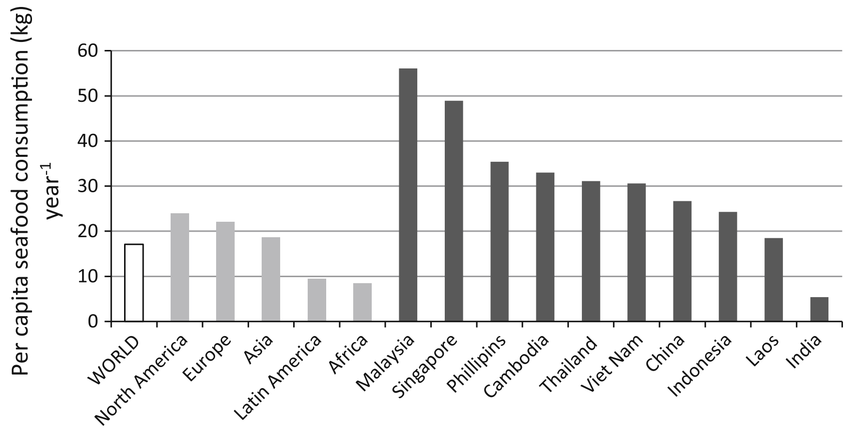

Fig. 1 Per capita consumption of seafood products (kg y^{-1}) (FAO 2010b). Many Asian countries show a high per capita consumption of seafood compared to other regions in the world

about half of all seafood products now originate from farming (FAO 2012a). Total aquaculture production in 2010 was 78 million tons, including aquatic plants (24 % of total production) (FAO 2012b). Aquatic plants are excluded from further analysis in this article, which instead concentrates on aquatic animals. The greater part (89 %, seaweed excluded) of aquaculture production originates from the Asia–Pacific region, with China standing out as the top producer. A recent forecast predicts aquaculture-based production of aquatic animals to reach up to 110 million tons in 2030, an increase of almost 100 % from current production (Hall et al. 2011).

Environmental Concerns—Impacts on Local and Global Scales

As with other food production systems aquaculture can negatively impact ecosystems and affect global flows of energy and resources. Environmental effects of aquaculture can be seen at various scales. Local effects include discharge of untreated effluents, spreading of aquatic animal pathogens and invasive species, and habitat alteration and related loss of ecosystem services. More global impacts involve release of greenhouse gases, unsustainable fishing behaviors in response to growing demand for fishmeal and fish oil, and, possibly also from an ethical and global resource management perspective, transformation of fish resources from human food to animal feeds (Naylor et al. 2000; Pauly et al. 2002; Klinger and Naylor 2012). Table 1 summarizes key environmental impacts of aquaculture production.

Eco-certification of Aquaculture

Concerns about the environmental impacts of aquaculture and growing demand for seafood products has led to increasing interest in mitigation measures. Market-based initiatives such as certification schemes and consumer recommendation lists for aquaculture and capture fisheries have become increasingly popular tools (Jacquet et al. 2009; Washington and Ababouch 2011). Certification schemes have been devised with various objectives in mind, from food safety, quality and traceability, to environmental and social impacts. Until recently, the majority of seafood certification programs have been applicable mainly to capture fisheries, but the number of certification schemes targeting aquaculture is growing steadily (Vandergeest 2007; Washington and Ababouch 2011) (Table 2). Key actors in the development of market-oriented standards include civil society and non-government organizations, governments, industry associations, retailers and supermarket chains and consumers concerned about food safety, and/or social and environmental impacts (Parkes et al. 2010; Washington and Ababouch 2011). A number of organizations working toward eco-certification are promoting a life cycle perspective in all standards for certification (Pelletier and Tyedmers 2008) and the International Organization for Standardization (ISO) 14020 series requires that life cycle considerations are included when developing standards for an eco-label (Mungkung et al. 2006). Despite this requirement, eco-certification programs for aquaculture and capture fisheries have been criticized for not adequately addressing biophysical demands and global environmental impacts (Pelletier and Tyedmers 2008; Thrane et al. 2009; Belton et al. 2010).

Why Certify?

Eco-certification schemes for aquaculture can be divided into two somewhat overlapping categories based on their target group and stringency level of standards (Environmental Law Institute 2008; Potts et al. 2011). The “gold standard” approach involves schemes where only top performers are certified and the eco-label serves as a guide for consumers to seafood produced in a strongly sustainable manner. Schemes with stringent standards, and potentially also certification focused on less environmentally

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Table 1 Environmental impacts from aquaculture and key references

Impact category	Activity/life cycle stage	Possible impacts	References
Habitat alteration	Conversion of natural terrestrial lands/wetlands	Biodiversity loss	Beveridge et al. (1994), Diana (2009)
		Loss of protection from storms, floods, and erosion	Barbier (2007), Walters et al. (2008)
			Walters et al. (2008)
		Loss of water purification	Millennium Ecosystem Assessment (2005), Mcleod et al. (2011)
		Loss of carbon sequestration	
		Reduced capture fisheries production	Walters et al. (2008)
		Loss of wetland products, e.g., wood, seafood, and medicines	Moberg and Rönnbäck (2003), Millennium Ecosystem Assessment (2005)
	Conversion of cropland	Salinization of soil and fresh water	Primavera (1997), Vandergeest and Flaherty (1999)
Feed	Forage fish fisheries	Overfishing of forage fish for fish meal and fish oil	Naylor et al. (2000), Deutsch et al. (2007), Tacon and Metian (2009)
	Terrestrial feed production	Impacts originating from crop production (e.g., soy and maize) to feed	Foley et al. (2011)
Effluents	Grow out phase	Nutrient leakage	Islam (2005)
		Pesticide and disinfectant leakage	Gräslund et al. (2003), Burridge et al. (2010)
		Antibiotic leakage	Gräslund et al. (2003)
Invasive species	Larvae production and grow out phase	Escapes of non-native species	Beveridge et al. (1994), Lind et al. (2012)
Diseases	Hatchery and grow out phase	Spread of diseases and parasites to wild populations	Toranzo et al. (2005), Krkošek et al. (2007)
Larvae production	Fry and broodstock fisheries	Discarded bycatch and biodiversity concerns	Rönnbäck et al. (2002)
Energy consumption	Consumption throughout lifecycle	Energy consumption throughout the life cycle	Troell et al. (2004), Pelletier et al. (2009)

Table 2 Selected certification schemes and certified quantities (thousand tons annually)

Certification scheme	Description of scheme	Quantities certified (thousand tons)	References
Global GAP	Private sector body. Business to business. No label	2000	GlobalGAP Annual report (2011)
Aquaculture Certification Council (ACC)	Trade association introduced by the industry. Business to consumer. Label	212	(More, personal communication)—ACC, 3/2/2012
Naturland	Organic. Business to consumer. Label	40	(Weber, personal communication) Naturland 17/10/2011
Soil Association	Organic. Business to consumer. Label	4	(Perrett, personal communication), Soil Association 18/10/2011
KRAV	Organic. Business to consumer. Label	0.7	(Finden, personal communication) Debio 14/10/2011
Debio	Organic. Business to consumer. Label	4.3	(Finden, personal communication) Debio 14/10/2011
AquaGAP	Business to consumer. Label	37	(Bedford, personal communication) Institute for Marketecology (IMO), 13/10/2011
Friends of The Sea	NGO. Business to consumer. Label	220	(Gledhill, personal communication)—FOTS 13/7/2011
Aquaculture Stewardship Council (ASC)	Business to consumer. Label	–[a]	–
Fairtrade[a]	Business to consumer. Label	–[a]	–
Total		2293	(4.2 % of total production 2010)

[a] Draft standards

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demanding species groups (such as bivalves and herbivorous fish), may fall under the "gold standard" category. The second and more inclusive (or pragmatic) type of scheme targets a larger group of producers and clearly has the objective to shift a substantial portion of the sector toward a better performance. The environmental and social criteria for compliance in the inclusive schemes are generally less strict than in the "gold standard" type, but may instead include a larger share of the sector. Experiences from other commodities have shown that schemes with less stringent criteria tend to attract a larger group of producers (Auld et al. 2008; Kalfagianni and Pattberg 2013). The aim of eco-certification of aquaculture could thus either be to guide toward strong environmental sustainability by promoting the best performers and production systems, and/or to work as a tool to improve practices for a larger share of the sector.

PURPOSE OF REVIEW

This review considers whether eco-certification could be an effective tool to mitigate the environmental impacts of aquaculture. Social and economical outcomes of implementation of eco-certification (for instance those affecting small-scale farmers) as well as standard criteria aiming to reduce negative social impact are indeed important considerations in understanding the implications of eco-certification programs. However, as the environmental outcomes from implementation of aquaculture eco-certification up till now have been less thoroughly examined, this article focuses solely on the environmental aspect. The analysis takes a sector-wide approach to explore the possibilities for environmental benefits from the application of certification schemes, with particular reference to the following questions:

Species

Which species are targeted in present aquaculture eco-certification schemes? Could the strategy for species selection be improved if certification is to provide a global environmental benefit?

Quantities

How much of global aquaculture is eco-certified today, and how much is likely to be covered in the future?

Production Systems

Which production systems and which producers are the primary targets for certification and is this coverage sufficient to reduce the environmental impacts of aquaculture?

Impacts

Does eco-certification effectively target the major environmental impacts of aquaculture?

METHODOLOGY

Eco-certification schemes were selected for analysis based on current and/or predicted market penetration share (Table 2). All schemes selected address environmental impacts as a stated objective. Some have been in operation for several years, whereas others are still under development or in early stages of implementation.

Species and Quantities

Each eco-certification scheme was evaluated regarding species coverage and approximate share (by volume) of the global seafood market. Information on targeted species and certified volumes was obtained through personal communication, literature search or from standard holders' websites. A few aquaculture operations have been certified against several standards, thus the total volume of certified seafood is likely to be marginally less than presented in Table 2.

Production Systems

The question concerning which production systems that are currently targeted by eco-certification schemes was examined through a review of peer-reviewed scientific literature (including also, e.g., FAO reports).

Impact Coverage

The potential environmental impacts covered were explored by examining the scope of different certification schemes and the extent to which differences between schemes might influence the environmental benefits associated with their application. The analysis focused on answering to what extent eco-certification schemes include criteria matching commonly used impact categories for life cycle assessment (LCA).

The impact categories investigated were global warming potential, energy use, eutrophication (ecosystem response to fertilization), and biotic resource use. The selection of categories was based on the frequency in which they have been used in previous LCA on aquaculture (Henriksson et al. 2011) and on relevance for the scope of this study. Other impact categories, for instance land use and eco toxicology, are also potentially relevant but were not included in this study. As utilization of forage fish for

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aquaculture feed has been considered a major challenge for future aquaculture development and expansion (Naylor et al. 2000), biotic resource use was assessed based on how standards address inclusion of fish meal and fish oil in feed. To provide an overview of the results, a scale ranging from 1 to 3 was applied:

1. Impact category not included in criteria for compliance.
2. Impact category mentioned in standards, but not with measurable criteria for compliance.
3. Impact category with metric compliance criteria.

To facilitate comparison of schemes, this part of the study was restricted to one commodity, shrimps and prawns. This group was chosen because environmental concerns have made it a priority for several certification schemes. KRAV and Debio have not developed standards for shrimp and were thus not included in the assessment. Around 20 standard documents for 8 certification schemes were analyzed.[2] Some environmental impacts of aquaculture are presently not addressed by LCA methodology (Hall et al. 2011), including biodiversity and ecosystem services loss due to habitat alteration and overexploitation of forage fish stocks. The significance of impacts falling outside the LCA framework and not covered adequately in present standards is discussed in the "Results" section.

RESULTS

Species Targeted by Certification Schemes

The present species coverage of eco-certification schemes restricts the potential environmental benefits as more than half of the species groups targeted make up less than 1 % each of the total aquaculture production (seaweed excluded) (Fig. 2). Carp comprises the largest aquaculture species group, making up ca. 40 % of the total world production by live weight (FAO 2012b), yet it is largely excluded from eco-certification. The only international schemes that have standards specifically developed for carp are Naturland and the Soil Association, which both presently have limited geographical coverage. Global GAP and GAA recently revised their criteria, which previously were intended for a set number of species, to include all aquaculture species. Other certification schemes that have generic standards for all aquaculture species are Friends of the Sea (FOS) and AquaGAP. However, Weymann (GlobalGAP) stated in a personal communication that no carp has been certified by Global GAP to date (2011), and AquaGAP (2012), Friends of the Sea (2012), and GAA (BAP 2012) have not certified carp either. Many carp farming systems are considered to generate low impacts (e.g., filter-feeding carps, integration with rice, etc.), but recent studies have shown environmental impacts associated with intensified farming systems using compound feed and fertilizers (Hall et al. 2011). The cumulative environmental footprint is significant (Hall et al. 2011). However, due to its inherently low environmental impact associated with limited dietary requirement for animal feed ingredients (e.g., fishmeal) there is likely a potential for significant improvements in environmental performance. The role of certification in achieving such improvements requires further investigation. Nevertheless, the omission of this species group from eco-certification programs limits the environmental benefits of certification for the global aquaculture sector.

Quantities Targeted by Certification

Currently, only around 4.2 % of the total production from aquaculture is estimated to be eco-certified (Table 2) and it is notable that GlobalGAP accounts for nearly 80 % of the eco-certified segment (Fig. 3). In the past 2 years, the volume of seafood certified by GlobalGAP has quadrupled (GlobalGAP 2012). However, earlier reviews conducted on how aquaculture certification schemes incorporate environmental integrity in their standards gave GlobalGAP low scores compared to other schemes (WWF 2007; Volpe et al. 2011). No information is currently available on environmental outcomes from implementation of GlobalGAP and the degree of environmental sustainability achieved by implementing the standards, as in all other aquaculture eco-certification schemes, thus remains unknown.

When predicting the potential of eco-certification to reduce the environmental footprint of aquaculture it is valuable to estimate how large segment of the total aquaculture production that is likely to be certified in the future. However, due to a number of uncertainties regarding how relevant constraints and drivers might develop in years to come (discussed in the next paragraph) it is challenging to conduct an accurate approximation of the growth of eco-certified seafood volumes. We found that certification schemes rarely present targets for certified volumes or anticipated market share.

The proportion of eco-certified aquaculture production in the future has to be framed in the context of projected growth for the entire industry, which is expected to produce up to 110 million tons annually (seaweed excluded) by 2030 (Hall et al. 2011). This is an increase by almost 100 % from current production, and consequently the volume of eco-certified production needs to double in the next two decades to even remain at today's relative

[2] A list of evaluated standard documents can be obtained from the authors upon request.

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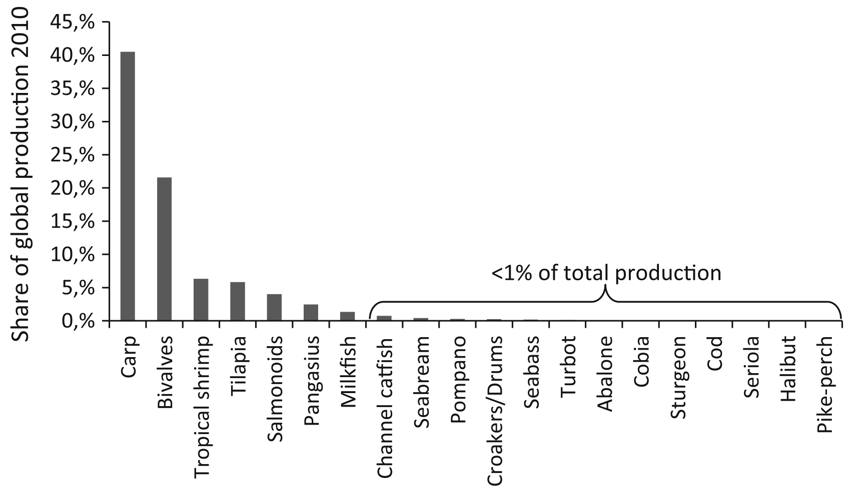

Fig. 2 Share of global production (seaweed excluded) of species groups targeted by eco-certification. More than half of the species (13 of 21) makes up less than 1 % each of the global production from aquaculture (*in bracket*) (FAO 2012b)

contribution of 4.2 % eco-certified. For the absolute volume of non-certified aquaculture production (currently around 52 million tons, seaweed excluded) to remain constant in the future, the volume of eco-certified production would need to reach at least 58 million tons by 2030 (assuming total aquaculture production of 110 million tons in 2030). This is clearly a major challenge given that only 2.3 million tons is eco-certified today (Table 2).

Market incentives for producers to enter certification are important drivers for participation in eco-certification schemes. A continued demand for eco-certified seafood in the US and Europe is thus a necessary condition for positive environmental outcomes from eco-certification. However, as the population and middleclass in Asia is growing fast alongside with seafood consumption, targeting Asian seafood markets is essential if eco-certified production is aiming for reducing the environmental footprint of the overall sector. As mentioned above, exclusion of species groups currently especially popular in Asia (such as carp) could limit the global environmental benefit of certification. Furthermore, with exclusion of carp the future potential proportion of the total aquaculture production certified will be limited, and consumers in, e.g., Europe and North America will not be provided with the choice of carp and similar species as sustainable seafood options.

Targeted Producers: Does Scale and Performance Matter?

Small Scale Versus Large Scale

Another critical hurdle to overcome to increase the certified share of seafood is inclusion of technically and financially weak producers in developing countries. Developing nations accounts for 80 % of world aquaculture production (FAO 2012a) and a high proportion of farms in many developing countries can be considered small scale (Umesh et al. 2010), for instance 80 % of Asian fish farmers (FAO 2006) (see Fig. 4). Small-scale aquaculture is poorly defined, but encompasses a highly diverse group of production systems (FAO 2009; Belton and Little 2011) ranging from low input extensive and integrated crop-fish cultivations aimed mainly for household consumption and local markets to small commercially oriented farms with production primarily for sale, either to domestic or export markets. The latter is especially true for high-valued

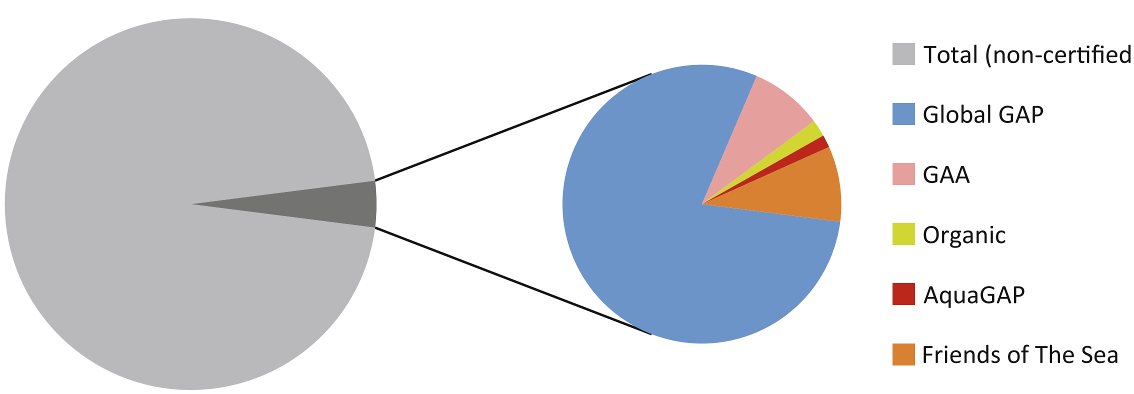

Fig. 3 Current eco-certified share of total aquaculture production and coverage of individual eco-certification schemes (data from 2010 to 2011)

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species such as shrimps and prawns (Belton and Little 2007). In this article, small-scale aquaculture includes farms usually utilizing a comparatively small farming land area, and also operations using primarily family labor, having limited economic turnover and minor opportunities for operational investments (see also definition in FAO 2009).

When in large numbers, small-scale operations can represent an environmentally significant component of the industry. Small-scale farms operated intensively likely accounts for a substantial share of the global aquaculture production, whereas extensive small holders utilize large land areas for maintenance of production. However, it is yet to be seen to which extent small-scale farmers can be part of certification programs, or if the barriers to compliance with standards and costs for certification are too great. Experiences from eco-certification of capture fisheries show that small-scale fisheries to a large extent have been excluded from certification, mainly due to lack of data and monetary resources (Jacquet and Pauly 2008). The Marine Stewardship Council (MSC) has been criticized for not adequately including small-scale fisheries (Jacquet and Pauly 2008; Gulbrandsen 2009). Initiatives for eco-labeling of forest products have met similar challenges with less than 10 % of the land certified by the Forest Stewardship Council (FSC) located in developing countries (Fischer et al. 2005). Concerns have been raised that small-scale aquaculture producers also will have difficulties paying for investment in production improvements as well as facing technical barriers to comply with standards (Subasinghe and Phillips 2007; Khiem et al. 2010; Belton et al. 2011; Bush and Belton 2011).

Environmental implications from exclusion of small-scale aquaculture producers, across the spectrum of small-scale production systems, from eco-certification have yet to be explored. Even though some commercially operated small-scale farms increasingly are using commercial feeds (Belton and Little 2007), a significant share of the small-scale operations still use lower inputs of feed or nutrients to maintain natural food production. Such semi-intensive or extensive systems are not only particularly dependent on input such as commercial feed and energy but also can require large culture areas per given quantity of seafood produced (e.g., extensive shrimp ponds in parts of Asia). In small-scale coastal systems, extensive farms have been located in or near sensitive ecosystems such as mangroves and other wetlands. Thus, even if extensive production systems are less demanding when it comes to external input such as feed and fertilizers, the land area appropriated for a given production volume is considerably larger than in intensive aquaculture operations (Lewis et al. 2003). Conversion of ecologically valuable ecosystems such as mangroves influences the supply of a range of ecosystem services, and the economic value of unconverted land can be higher than areas modified to aquaculture (Millennium Ecosystem Assessment 2005; Mcleod et al. 2011). If small-scale aquaculture farmers are not targeted by eco-certification, the environmental impacts from such systems will not be reduced. This could be a significant, yet unquantified, environmental concern given that 80 % of world aquaculture production originates from developing countries (FAO 2012a), with large numbers of small-scale operations. Further research is needed on categorization of different scales of systems, impacts, environmental

Fig. 4 Fishing in shrimp ponds. Aceh, Indonesia. The majority of seafood farmers in Asia can be defined as small-scale and are at risk of being excluded from eco-certification due to economic and technical constraints. Photo: Flickr/Mike Lusmore, WorldFish

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management options, including certification programs where relevant.

Best Performers Versus Worst Performers

Quantifying environmental outcomes from implementation of eco-certification schemes is challenging (Ward 2008). In the Aquaculture Dialogues draft standards for shrimp (when in operation, labeled by ASC), the target is to certify 20 % of the top producers (ShAD 2011). This approach is based on an untested hypothesis that certification of the best performers will provide the necessary incentives for others to improve. It is unclear whether focusing on the best performers will have substantive impact on the environmental performance of individual species groups, let alone the aquaculture sector as a whole. When the main target is producers that already perform well, the environmental benefits may be limited as farmers applying higher impacting practices might be excluded from certification (particularly if other market channels exist for such producers) (Fig. 5).

According to the push-threshold model for eco-certification of seafood developed by Tlusty (2012), farms which are performing well enough to comply with standards will likely not improve much further. This model also suggests that farmers that are too far below the certification threshold will unlikely invest in improvements to comply with certification standards, even if they have access to the skills and investments required (Phillips et al. 2011; Tlusty 2012). It thus seems unlikely that certification of the best performers will shift the whole aquaculture sector toward a better overall performance, unless market coverage for certified products can be substantially increased. Rather, the large majority of producers will likely not change their practices substantially as the performance gap to reach the certification threshold will be too large, and market pull will be insufficient. According to Tlusty (2012), the shift toward better practices can only come from the very limited share of the aquaculture sector made up from farmers positioned just under the threshold. The push-threshold model, however, does not consider the pull effect on the consumer end of the production–consumption chain, such that an increased demand for labeled seafood could give producers incentives to improve their practices.

Does Eco-certification Target the Major Environmental Impacts from Aquaculture?

Eco-certification Schemes Through the LCA Lens

The environmental benefits from eco-certification also relate to the scope of the scheme, and whether it is targeting the key impacts. This aspect has been analyzed before (Corsin et al. 2007; WWF 2007; Parkes et al. 2010), and we focus on one species group, shrimp and prawns, to indicate the implications of scope for overall environmental performance. The results suggest a tendency among the schemes investigated of a low-to-moderate level of inclusion of the selected impact categories (Table 3).

Global Warming

Measures for reducing impacts on global warming had limited inclusion in most eco-certification schemes. FOS, however, included a section regarding calculation of the global carbon footprint per unit of produced product and annual improvements, while the Soil Association recommended using renewable energy sources when possible. Nevertheless, these recommendations were not mandatory for compliance.

Energy Demand

All investigated schemes included requirements or recommendations for record keeping of energy consumption.

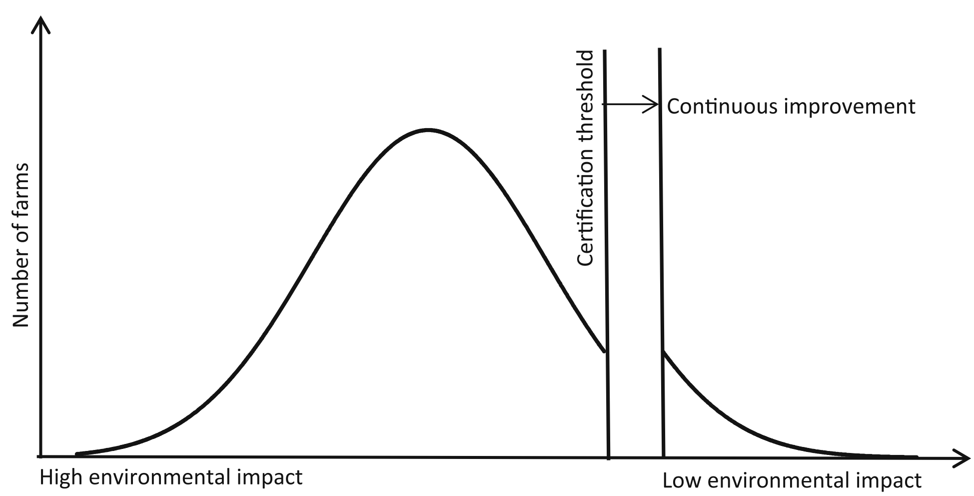

Fig. 5 When certifying the best performers, many farms will be left behind. The producers in the *left end* of the graph, the worst performers, will likely not invest in technical improvements to reach the certification threshold; the gap to comply with certification standards is too wide

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Table 3 Selected certification schemes and level of inclusion of LCA-impact categories in standards for shrimp and prawns. The ranking from 1 to 3 indicates level of inclusion in standards: 1. Impact category not included in criteria for compliance. 2. Impact category mentioned in standards, but not with measurable criteria for compliance. 3. Impact category with metric compliance criteria

Scheme	Global warming	Energy demand	Eutrophication	Biotic resource use	Total
GAA	1	2	3	2	8
Global GAP	1	2	2	2	7
Naturland	1	2	2	2	7
Soil Association	2	2	2	2	8
Friends of the Sea	2	2	2	2	8
AquaGAP	2	2	3	2	9
Aquaculture Dialogues (to be ASC)[a]	2	2	3	2	9
Fairtrade[a]	1	2	2	2	7

[a] Draft standards

Though the wording in some standards indicated that it is preferable to reduce total consumption and to utilize renewable energy sources, no schemes required a reduction of total energy use or a change from non-renewable to renewable energy sources. Moreover, the focus in the standards was solely on energy consumption at the farm level, and only in one case, record keeping of energy use in processing facilities and hatcheries. This is notable, as feed production can be the most energy-demanding life cycle stage in shrimp production (Cao et al. 2011).

Eutrophication

All standards included criteria aimed at reducing eutrophication, though the level of inclusion of metric measure points varied. The draft standards from the Shrimp Aquaculture Dialogues, for instance, specified the allowed amount of nitrogen and phosphorus release from the system and set a limit for solids in the effluent water. The focus was exclusively on the farm level.

Biotic Resource Use

Although all the schemes acknowledged the need to lower the dependence on fish meal in feeds, the standards were not of compliance or non-compliance type and did not include well-defined metric measure points. From an LCA perspective, the amount of forage fish in feeds and the trophic level of these species are of importance; species at a high level implies higher net primary production appropriation. None of the schemes included criteria related to trophic level of the species used for fish meal.

Environmental Impacts not Addressed by LCA

Feed represents a significant source of environmental impact (Fig. 6). One of the major challenges for aquaculture eco-certification schemes is to assure full traceability of fishmeal and fish oil and guarantee that the fish come from well-managed fisheries and viable fish stocks. All standards in the study included criteria for fishmeal and fish oil and also acknowledged the need to ensure that endangered fish species are not used for production of shrimp feed. Though the availability of certified fishmeal and fish oil is increasing, eco-certification of aquaculture feed is still in its infancy. Limited supply of certified fishmeal and fish oil likely constrains the development of standard criteria requiring shrimp feed to be sustainably sourced. GAA, for instance, required 50 % of fishmeal and fish oil to be eco-certified by 2015, and the draft shrimp standards developed by the Aquaculture Dialogue allowed uncertified feed for an interim period of 5 years from standard publication. These examples illustrate that eco-certification presently is not a guarantee for usage of sustainably sourced feed, probably more for practical reasons, though there is increasing interest in this issue.

Habitat alteration and potential loss of ecosystem services are presently not addressed by LCA. For shrimp culture, mangrove deforestation for establishment of ponds has historically been one of the main environmental concerns (Lewis et al. 2003; Walters et al. 2008). All of the selected schemes emphasized the importance of preservation of the mangrove ecosystem. However, criteria related to re-plantation were often vaguely phrased. The majority of schemes did not require an audit of whether the re-plantation had been successful. Moreover, some schemes allowed farms to contribute with monetary funding to re-plantation programs to compensate for mangrove loss. The audit process of rehabilitation programs far from the farm seems uncertain.

DISCUSSION

This article has analyzed whether eco-certification is or could be an effective tool in reducing the negative

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Fig. 6 Utilization of forage fish has been considered a substantial challenge for future aquaculture development. **a** Landings of fish aimed for feed production or direct usage in aquaculture operations, Guangzhou, China, **b** shrimp feed from Thailand containing fish meal. Photo: **a** Max Troell, **b** Malin Jonell

environmental impacts of aquaculture. The following discussion focuses on six key points arising from the analysis.

1. Species selection and environmental impacts are poorly matched, with more than half of the species targeted for eco-certification constituting less than 1 % each of total global production.
   The selection of species for eco-certification appears not to correspond fully with the environmental impacts. It is notable that large eco-certification initiatives, such as the Aquaculture Dialogues (AD), have invested time and economic resources to develop standards for species such as *Seriola* and *Cobia* (produced in small quantities and having limited environmental footprints at a global scale), while standards for carp, which makes up 40 % of global aquaculture production, have not been developed. The selection of species for the AD was reported to be based on environmental impact, market value and/or trading on the global market (WWF 2012), but has focused almost exclusively on markets in developed countries. Given that the consumption of seafood is expected to increase considerably in the Asia–Pacific region, more focus should be on species produced and consumed in this region (Fig. 7). While the environmental impact per kilogram animal protein produced is comparatively low for carp production in most impact categories, an assessment of the consequences of its exclusion from eco-certification schemes appears necessary due to its global significance.
2. The eco-certified share of aquaculture production (by volume) is currently small and will likely remain limited.
   Eco-certified seafood presently constitutes only a minor share of total aquaculture production and the effect on the environmental footprint of the sector as a whole is currently uncertain. Furthermore, low demand of eco-certified seafood from the growing Asian market, exclusion of major species groups from certification and limited coverage of the spectrum of production scales, particularly small-scale producers, indicates that the bulk of aquaculture production likely will remain non-certified. Global aquaculture production (seaweed excluded) has been projected to potentially increase by almost 100 % by 2030 (Hall et al. 2011). This projection would imply that eco-certified production needs to increase from 2.3 million tons (2010) to almost 60 million tons by 2030 to avoid a significant net increase in non-certified production globally.
3. Excluding small-scale farmers could limit the environmental benefits of eco-certification.
   Experiences from eco-certification of capture fisheries show that small-scale producers in developing countries are heavily underrepresented. Concerns have been raised that present eco-certification schemes for aquaculture are also primarily targeting large scale, technically advanced enterprises and might exclude small-scale producers. An understanding of the

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Fig. 7 Eco-certification likely needs to focus on Asian markets in a larger extent to substantially improve the aquaculture sector. **a** Man selling carp on market in India, **b** seafood market in Hong Kong, China. Photo: **a** Max Troell, **b** Hampus Eriksson

environmental impacts of the different farming scales and system types is necessary to target the most effective interventions, but our analysis suggests a further gap in coverage of the aquaculture sector, implying again a reduction in the potential environmental benefits from certification as currently practices. It seems somewhat contradictory that present eco-certification schemes mainly focus on environmental impacts apparent on a local spatial scale (see point five below), while at the same time they are directed primarily toward large scale, intensive farms, which arguably are more dependent on inputs (energy, feed, etc.) from external ecosystems than extensive farms.

4. Targeting solely the best-performing operations could leave the farms with the highest environmental impact behind.
   The push-threshold model (Fig. 5) suggests that the vast majority of producers will not substantially change production practices due to introduction of eco-certification into aquaculture. The worst performers situated too far from the certification threshold will likely not invest financially in sufficient improvements needed to comply with certification standards. Consequently, producers will then continue to have a market for low-cost seafood despite the development of aquaculture certification. Environmental impacts from higher impact production systems may, therefore, need other measures, including effective national legislation or other public or private voluntary management alternatives (Phillips et al. 2011).

5. A long-term biophysical sustainability perspective is generally lacking in the schemes.
   The schemes investigated in this study show a moderate to low level of inclusion of commonly used LCA categories in their standards for shrimp aquaculture, suggesting that match of current standards to impact categories could be improved. Though the LCA analysis was solely considering standards for shrimp, the findings are likely also applicable for other aquaculture species as the impact categories investigated are not specific for shrimp culture. The lack of criteria to regulate impact on climate change, reduce energy consumption and biotic resources are of particular concern. LCA-impact categories such as overall energy use and impact on climate change, together with impacts outside the LCA framework such as full traceability of feed and fish meal, are often beyond the scope of individual farmers. However, measures such as lowering the total energy consumption and reducing the dependence on supplementary feed can be implemented at the farm level. Notwithstanding the importance of regulating *amounts* and *trophic level* of fishmeal used, ensuring sourcing from sustainable fisheries, or alternatively from fish trimmings, is of high significance and is a challenge for future aquaculture development. Sustainable sourcing of fishmeal and fish oil has not yet been addressed adequately. Eco-certified reduction fisheries, such as those certified by the Marine Stewardship Council (MSC) and the International Fishmeal and Fish Oil

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Organization (IFFO), are becoming more numerous but are not yet producing sufficient amounts of fishmeal and oil to supply the eco-certified aquaculture sector. While outside the scope of this article, earlier study on eco-certification of capture fisheries (including forage fisheries) has revealed weaknesses in the content of the standards and also in the implementation and evaluation of certification schemes for capture fisheries (Jacquet et al. 2010; Stokstad 2011; Froese and Proelss 2012). A focus on carnivorous species in eco-certification programs without addressing the feed issue at a more sectoral level could do more harm than good for the environmental performance of the sector. Utilization of sustainably sourced feed from certified fisheries is, however, complex as reduced inclusion of fishmeal/oil for some species does not automatically result in more forage fish being allocated for direct human consumption (Alder et al. 2008).

CONCLUDING REMARKS

This review suggests that as currently practiced and projected eco-certification risks having limited influence on the global environmental impact of the growing aquaculture sector. The conclusion is based on anticipated limited species coverage, difficulties in incorporating all scales of impact and production systems, focus on markets in US and Europe, limitations in applicability in developing countries' markets, and coverage of impact categories within certification standards. The environmental outcomes of eco-certification may potentially also be limited by a lack of differentiation among species groups. Currently, certification programs either (a) apply very stringent standards and exclusively target production systems that are better performing, with likely marginal environmental impacts or (b) apply more inclusive standards targeting an industry segment with significant environmental concerns. An overarching objective for the latter type of eco-certification scheme is to promote a shift to environmentally improved production practices over a substantial segment of the sector. At the same time, it may be argued that the seafood movement with certification organizations in the vanguard is promoting only small improvements instead of setting strong sustainability as a minimum threshold for standard compliance (Environmental Law Institute 2008). Even if eco-certification of individual farms implies that better and more responsible methods are practiced, this does not necessarily mean that the production system is sustainable, i.e., somewhat less unsustainable does not imply sustainable. Present certification programs for aquaculture need to balance the risk of losing credibility and consumer trust with the endeavor to attract a large enough portion of the sector to actually reduce the environmental footprint of the sector. A crucial question is to what extent and under which circumstances, e.g., for which species groups and production systems, these two aspirations are possible to combine.

Eco-certification of aquaculture has so far focused on certification of some environmentally demanding species groups such as salmon and shrimp, mainly produced for consumption in wealthy parts of the world. Species groups that have the potential to be produced in large quantities with marginal environmental impacts, such as carp, have not been targeted by any major certification program. Figure 8 is a conceptual graph that illustrates the environmental performance of three species groups and their potential certification thresholds. As shrimp is more demanding to produce than carp across most impact categories, fewer producers would in theory be certified from an environmental sustainability perspective. The figure also illustrates that an eco-certified shrimp might have a larger impact on the environment than a non-certified carp or mussel.

Although eco-certification could trigger improved practices for a variety of species in individual farms, the improvement of the sector as a whole would probably be insignificant if the differences in environmental performance of species groups are not taken into account. If the target is to certify producers with minimum environmental impacts, a larger share of carp than shrimp farms would be eco-certified. The consumers and, perhaps more important, retailers, thus need information about differences in environmental impact of different commodities. If the feasibility of environmentally sustainable aquaculture production is reflected in volumes of eco-certified commodities, eco-certification could have an important role to play in the future.

Recommendations for Improving the Potential for Eco-certification as a Tool Toward Improved Environmental Performance of Aquaculture

- Additional species need to be explored for eco-certification. Omnivorous and herbivorous species can be produced with relatively little impact on the environment (though sometimes requiring large areas for production) and could thus be targeted by eco-certification.
- There needs to be an increased focus on markets and consumers in Asia, where seafood consumption is predicted to increase substantially. More research on Asian retailers' and wholesalers' perceptions of certified seafood is also of importance. The expansion of supermarkets in developing regions has primarily taken place during the past 20 years (Reardon et al. 2010) and

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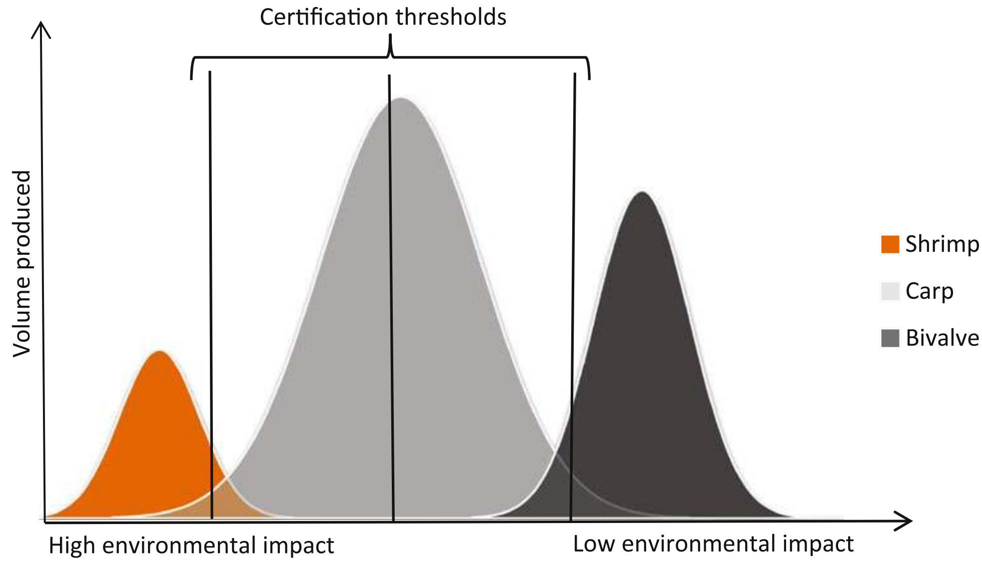

Fig. 8 Schematic figure illustrating the effects certification may have on the environmental performance of three selected species groups: shrimp, carp, and bivalves. The three parallel lines illustrate the potential certification thresholds for the three species groups

can potentially be of great significance for the entrance of certified commodities into new markets (Washington and Ababouch 2011).

- Investment in technical and financial assistances for small-scale farmers and enterprises that face barriers to certification is required to enable their participation in certification programs. Small and medium enterprises in developing countries broadly lack access to financial and technical services and environmental benefits from certification might be increased by programs targeting this important component of the aquaculture sector.
- Standards should be better aligned with environmental impacts of different aspects of aquaculture. Improved criteria for sourcing sustainable feed ingredients, habitat rehabilitation for biodiversity and ecosystem services, and reduction of energy consumption and impacts on climate change deserve particular attention. Ecosystem or area-based approaches may be required to address impacts beyond the individual farm.
- Standardized assessment methods for evaluating environmental and ecological outcomes from eco-certification should be implemented. Guidelines are available, for example from ISEAL (2010), but yet have to be implemented. Certification is largely conducted at the farm level; however, assessments of the environmental impacts from implementation should also be conducted at larger spatial scales. Such assessments could provide guidance for improvement and better targeting of interventions to minimize negative impacts.
- The hypothesis that eco-certification for aquaculture should focus on the best-performing operations to reduce environmental impacts should be tested. The certified share of the production would likely differ among species, depending on the feasibility of implementing environmentally sustainable practices. The remaining segment of worst performers needs other measures, such as implementation of national legislation, trade agreements, and even perhaps lowered consumption targets for some commodities.
- Finally, certification should be viewed as only one intervention to improve the environmental performance of the aquaculture industry. While improvements can certainly be made to current and planned certification programs, a wider tool box of regulatory and non-regulatory measures will be essential for environmental management of aquaculture as it continues to grow.

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