Environmental supply chain management in the seafood industry: past, present and future approaches.

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Abstract

This review discusses and analyses the results of previous results in identification, development and implementation of cleaner production strategies within the seafood industry. The relevant peer reviewed articles were identified from a structured keyword search and analysed by both supply chain stage (capture/aquaculture, transport, processing, storage and retail), and examination of the cleaner production strategies implemented. Results found entities along the seafood supply chain generally worked separately to improve cleaner production processes and outputs to grow their own businesses. Whilst this approach can be beneficial, it ignores the broader cleaner production potential benefits gained when applied across multiple supply chain entities. The most effective cleaner production strategies for improved environmental performance in each sector of the supply chain were identified with the potential to reduce unnecessary handling, energy usage, storage costs and waste production. To ensure the greatest reduction in environmental impact, a whole of supply chain management system that incorporates life cycle assessment modelling is recommended.

Keywords: Seafood, cleaner production, supply chain management, life cycle assessment, resource use

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1. Introduction

In the past, the seafood supply chain has worked separately in an effort to improve their processes and outputs to grow each individual business. As separate entities, each company within the value chain progresses with social, economic and environmental improvements, but only if it benefits their business directly. Jensen et al. (2010) demonstrates in a general supply chain model, collaboration with the whole supply chain increases both product quality and profit by using the same quantity of resources to meet the demand of the final product, rather than the direct customer. Thus, to continue the growth of the seafood industry, individual companies need to communicate and develop strategies with their suppliers and customers to increase the effectiveness of cleaner production strategies (van Hoof and Thiell, 2014) in the seafood industry.

Implementing environmental supply chain management systems should result in monitoring and subsequent improvement of the environmental impact within the seafood industry. The management practice should include all stages of the supply chain, incorporating the environmental impact along the whole life cycle of the product (Gupta and Palsule-Desai, 2011). Supply chain collaboration also creates a competitive advantage over businesses working individually; hence improving environmental performance through collective efforts (Cao and Zhang, 2011; Li et al., 2006). Moreover, investing in a whole of supply chain management program presents an innovative approach to shareholders, demonstrating an effective use of resources in their commitment to cleaner production (Bose and Pal, 2012). There is limited environmental research in the seafood industry; therefore, this paper reviews the cleaner production strategies implemented and their limitations across the seafood supply chain.

The objective of this review is to identify the cleaner production practices in the seafood supply chain and discuss the limits, successful examples and recommendations to reduce the environmental impact within the industry and to identify the knowledge gap requiring further research. The structure of this paper is as follows: overview of literature reviews in seafood; methods used within this paper; sectoral cleaner production strategies of the seafood supply chain; whole supply chain assessment and management; discussion; and conclusion.

2. Scope of the review

This paper reviews the environmental aspect in seafood; that is, the efficient use of resources for fish capture, processing and marketing. The social aspect of sustainable seafood is covered in Coulthard et al. (2011) and Moore et al. (2013) and is therefore excluded from this review. Cleaner production strategies (CPS) will be applied as the framework in this review to critique the environmental objectives in the seafood industry.

Prior literature reviews in global seafood industries and the management of the industry (twenty-five reviews since 2001) do not assess environmental impact along the entire supply chain. Instead they refer to specifics such as by-catch (Bellido et al., 2011; Catchpole and Gray, 2010), wild caught harvest (Crowder et al., 2008), fisheries and aquaculture management (Bjørndal et al., 2004; Caddy and Cochrane, 2001; Gamborg and Sandøe, 2005; Gauthier and Rhodes, 2009; Lima dos Santos and Howgate, 2011; Naylor and Burke, 2005; Partridge et al., 2008; Weir et al., 2012) and the difference between them (Pelletier et al., 2007), fish waste (Ferraro et al., 2010; Gehring et al., 2011; Jayasinghe and Hawboldt, 2012; Kim and Mendis, 2006) including wastewater (Chowdhury et al., 2010; Kitis, 2004; Leitão et al., 2006; Terada et al., 2011), feed production (Cho and Bureau, 2001; Francis et al., 2001; Tacon and Metian, 2009; Torrissen et al., 2011), and the application of the life cycle assessment tool in seafood (Vázquez-Rowe et al., 2012a). During this study, no previous review of the seafood supply chain interactions was found; either environmental reviews or general seafood supply chain interactions.

3. Methods

This study forms part of a wider literature review in supply chain management in the seafood industry. Therefore, the aim of this paper is to review the CPS applied in the various stages of the seafood supply chain and evaluate the effectiveness of the CPS implemented.

Methods of this study were based on recommendations by Seuring and Gold (2012) and started with a structured keyword search in the following databases: Ebsco, Springerlink, Wiley Interscience, Elsevier ScienceDirect, and Emerald Insight which identified papers for inclusion. Keywords included “seafood”, “fish”, “fisheries”, “supply chain”, “sustainable/sustainability”, “environment (al)”, “life cycle assessment” and “carbon footprint". Three relevant reports found by google using the keywords "fish", "seafood", "energy", "report" and "carbon footprint" and two book chapters were included.

Subsequently, sources were selected using the following criteria:

- Scientific research from the last fifteen years;
- Demonstration of CPS implementation and results
- Forward supply chain
- Published in English
- Not referred to in Crowder et al. (2008), a previous review in seafood supply chain management

3.1. <u>Sample and descriptive analysis</u>

Figure 1 shows the publication years of the sources used. Only twelve (15.8 %) were published before 2005, as Crowder et al. (2008) already reviewed this area. There are peaks in 2011 and 2012 with 17 and 16 sources respectively.

Of the 76 resources selected, ten (13%) came from The Journal of Cleaner Production, five (7%) from The International Journal of Life Cycle Assessment, four (5%) from Environmental Science and Technology and three (4 %) from the Aquaculture; Bioresource Technology; Food Chemistry; and Resources, Conservation and Recycling journals. Three were reports, two were book sections and one conference paper. The remaining resources used came from a range of peer reviewed journals.

3.2. <u>Categories for analysing the content</u>

The methods and findings of the reviewed articles were then categorised into the five CPS described by UNEP (2002) and van Berkel (2007) and by the various supply chain stages in the seafood industry: aquaculture, wild capture, transport, packaging and processing, storage, and retail.

For the purposes of this paper, the following aspects are used: environmental supply chain management is working as a whole supply chain with the intention of reducing life cycle environmental impact, enhancing social equity and saving costs; eco efficiency is increasing production using fewer resources; hotspots are the areas of greatest environmental impact; and CPS are operational changes implemented by industry to reduce the impact per kilogram (kg) of fish and are referred to in the following categories as described by UNEP (2002):

1. Good housekeeping: low hanging fruits, requiring no specialized skills, just needs common sense
2. Input substitution: replacing resources with environmentally preferred substances
3. Technological modification: modifying existing structures to increase efficiency
4. Product modification: modifying a product to reduce material consumption and to enhance recyclability
5. Recycling waste

Table 1 lists the papers reviewed on cleaner production strategies applied to reduce the impact within the seafood supply chain. All strategies were classified by their place within the supply chain (aquaculture, wild capture, transport, processing and packaging, storage, retail and the whole supply chain) (Table 1).

4. Sectoral cleaner production strategies of the seafood supply chain

The seafood supply chain consists of capture (wild caught or aquaculture), transport, processing and packaging, storage and retail. The following section identifies research that underpins the development of specific CPS and their implementation in each supply chain stage.

4.1. Aquaculture

Aquaculture, the farming of aquatic organisms such as fish, molluscs, crustacean and plants (Jerbi et al., 2012) involves many activities that potentially cause environmental impacts including feed production, breeding, fish growth and harvest. As researchers agree feed production has the biggest environmental impact on farming (Aubin et al., 2009; Boissy et al., 2011; Jerbi et al., 2012; Pelletier et al., 2009; Winther et al., 2009), this section will only cover CPS applied in the feed production aspect of aquaculture. Despite life cycle assessments (LCA) applied in aquaculture research (Ellingsen and Aanondsen, 2006; Jerbi et al., 2012; Pelletier et al., 2009; Tlusty and Lagueux, 2009), there is little understanding in how applying CPS within this supply chain section may benefit the entire seafood supply chain. Therefore, this section reviews the CPS recommended so far in aquaculture facilities.

One reason for the high impact of feed is the energy required. LCA studies demonstrated up to 90 % of all energy use in aquaculture is from producing feed (Pelletier et al., 2009). However, it is difficult to quantify the hotspots of feed production as there is no breakdown of published analyses (Aubin et al., 2009; Bosma et al., 2011; Parker and Tyedmers, 2012; Pelletier et al., 2011). Yet, the predominant environmental issues are generally the energy consumption, the ingredients used and the feed quantity required per kilogram of fish.

Another reason for the high impact of feed is associated with the harvesting of the fish used for feed. For example, krill harvested in Antarctica required transportation to shore in its natural form, using diesel in boat fuel, before drying into feed (Parker and Tyedmers, 2012). Increasing the harvest quantity per trip (Parker and Tyedmers, 2012) and reducing fuel consumption by 40 % during harvest (Ziegler and Hansson, 2003) were shown to improve energy efficiency, implementing the ‘good housekeeping’ CPS.

The impact of the feed depends on the ingredients used. The food chain influences the emissions as ocean carnivores release nitrogen and phosphorous wastes (Aubin et al., 2009) from a high protein diet. Therefore, Ellingsen and Aanondsen (2006) recommend vegetarian diets as they have a lower environmental impact. Yet, a vegetarian diet is not necessarily as efficient, as it reduces the growth rate, the quantity of feed required, the energy productive value and the lipid intake of the fish after 85 days (Espe et al., 2006). In contrast, Glencross et al. (2012a; 2012b) argued that digestion of a vegetarian diet depends on both the species of fish and the polysaccharide used. Consequently, the diet of fish may influence the environmental outcome (a product modification CPS).

So, measuring the carbon footprint of the aquaculture sector has found the feed has the greatest impact and highlights potential CPS to reduce this.

4.2. Wild capture

Wild caught fish harvested from their natural habitat have a different environmental impact to aquaculture fish. Vázquez-Rowe et al. (2011) found the seafood capture had the highest impact of the supply chain. Although LCA's have been widely used in wild caught seafood (Ellingsen and Aanondsen, 2006; Thrane, 2006; Vázquez-Rowe et al., 2010, 2011; Vázquez-Rowe et al., 2012b; Ziegler and Hansson, 2003; Ziegler et al., 2003), research is lacking in how their use benefits the entire seafood supply chain. Therefore, this section reviews the CPS applied within the wild capture section of the supply chain.

CPS have been recommended and applied to wild caught fisheries to reduce diesel use. For example, Wakeford (2010) recommended reducing water resistance by increasing the vessel length, and reducing the air resistance by clearing the deck and improving the mast. Ziegler and Hansson (2003) found modifying the tackle reduced fuel consumption. Sterling and Goldworthy (2007) discussed alternative energy sources to diesel, including biodiesel, but found all had a low energy density that was not suited to power boats. Instead, Sterling and Goldworthy (2007) recommended choosing the type of engine required to the purpose as slow speed engines use less diesel than high speed. Skipper interviews conducted by Marriott et al. (2011) instead identified equipment already in use including GPS and colour sounder installation as the best available equipment to increase fishing efficiency. All of these are examples of technology modification CPS that are available to wild capture fisheries to reduce their fuel consumption

The efficiency and thus, environmental impact, can also be reduced by minimising by-catch. By-catch is the term used for fish discarded at sea because they are undersized, they are not a species that sells well or the operation has met its' quota and wants to keep the species that bring a larger profit (Bellido et al., 2011). Bellido et al. (2011) recommended four points to reduce the fish by-catch; understand the quantity of fish available and work with it, improve selective processes to catch targeted fish (a "technology modification" CPS), develop methods for management decisions and finally, let the public get involved to engage industry to improve their practices. By using these techniques, the proportion of fish sold to those captured will increase, improving the efficiency of the harvest process and thus, reducing the environmental impact per kg of fish.

Minimising the by-catch brought to shore by creating new products is another way of improving the efficiency and environmental impact of the wild capture stage. Unused fish can easily be made into fertiliser (López-Mosquera et al., 2011), biogas (Eiroa et al., 2012; Kafle et al., 2013), and hydrolysate (Aspmo et al., 2005; Bhaskar and Mahendrakar, 2008; Nges et al., 2012). By recycling instead of disposing of unwanted fish the resources already utilised by the wild capture sector are then spread over a larger quantity of fish, thus increasing efficiency.

Consequently, CPS strategies have been applied in the wild capture sector to reduce fuel consumption and by-catch.

4.3. Transport

Although transporting fish between stages of the supply chain is an important process, its environmental impact is minor compared to seafood capture (Andersen, 2002; Weber and Matthews, 2008) and other areas of the supply chain (Ellingsen et al., 2009; Iribarren et al., 2010b; Thrane, 2006; Ziegler et al., 2003). The environmental impact of transport in the seafood supply chain is difficult to measure as it depends on production and distribution costs (Tlusty and Lagueux, 2009). Therefore, it is important to classify the mode of transport and the impact of processing when developing CPS.

The method of transport affects the environmental impact (Coley et al., 2011). Travel by ship has a low impact, but requires the product to be frozen due to the length of transport time (Tlusty and Lagueux, 2009) in order to maintain quality. For a frozen product, transportation by ship has been shown to have the lowest environmental impact, followed by truck and then air freight (Vázquez-Rowe et al., 2012b). Also, to deliver fresh fish from Norway to East Asia and United States of America via truck and aeroplane required ten times the energy required to transport frozen fish by truck and ship (Andersen, 2002). Kissinger (2012) suggested three steps to reduce the emissions from these transport methods including recording the distances the food travels, letting consumers know the impact the travel is having on the environment and increasing the efficiency of the transport methods used. By analysing the transport methods and environmental impacts, CPS can be developed to increase efficiency and reduce the carbon footprint.

The method of transport, and thus the environmental impact, also depends on the processing techniques used. Due to the refrigeration energy consumption and costs, Andersen (2002) recommended processing such as drying, smoking or freezing before exporting out of the continent (Bezama et al., 2012). Consequently, it no longer needs overnight delivery, instead using alternative long term transport methods like ship or trucks and, thus, reducing the energy used in transportation (Andersen, 2002).

Thus, the transport sector is important to consider within the seafood supply chain as the mode of transport chosen relies on the processing and final product.

4.4. Packaging and processing

The method of packaging fish differs according to purpose, thus, resulting in different environmental impacts. The packaging system used is influenced by the final market (Sanyé et al., 2012) and assists in reducing drip loss by restraining the fluid retention in the fillet (Williams and Wikström, 2011). Although processing and packaging requires energy, Williams and Wikström (2011) justify a 20 % energy increase if it is associated with different packaging techniques that maintain the final weight of fish. If shelf life extension is needed, Pardo and Zufía (2012) recommend modified atmosphere packaging as energy, heat and power are significantly less than thermal pasteurisation and high pressure processing. Modified atmosphere packaging (MAP) involves gas flushing the product, usually with carbon dioxide to increase shelf life. If an extended shelf life is not required, packaging in plastic bags is a better alternative as fewer resources by weight are required (Hospido et al., 2006). Depending on the purpose of the product, a packaging method can be designed to reduce the environmental impact, applying the “product modification” CPS.

Within fish packaging and processing facilities, attempts have been made to apply CPS. Bezama et al. (2012) successfully involved processors to monitor and reduce their energy consumption using cleaner production agreements – in this case, a set of specific opportunities to reduce the environmental impact were documented, signed by volunteer processors and the progress monitored by external audits. The regular monitoring identified problematic areas and lead to: increased maintenance of refrigeration equipment (good housekeeping); implementation of wastewater treatment systems (recycling waste); and implementation of machinery best practice, maintenance and preventative measures (good housekeeping). Hence, by keeping the facilities accountable through follow up audits, the packaging and processing facilities implemented good housekeeping and waste recycling CPS.

Maintaining product quality, especially within processing facilities is an example of a good housekeeping CPS. By implementing a quality assurance system such as HACCP (Hazard Analysis and Critical Control Points, a quality control system used to identify and prevent chemical, biological and physical contamination in the food industry) in a processing environment, regular product monitoring will result in a higher quality product and fewer rejected products, thus reducing both product and resource wastage (Lupin et al., 2010). Therefore, by managing the product quality from the beginning, the quantity of rejects can be reduced, resulting in a higher yield and reduced waste and thus, a higher efficiency of resource utilisation (Zugarramurdi et al., 2004; Zugarramurdi et al., 2007). Reducing fish wastage mitigates methane and carbon dioxide emissions released in the anaerobic digestion process (Hall, 2011) (breakdown process of fish fat, protein and carbohydrates, eventually resulting in methane, carbon dioxide and hydrogen gas emission). Consequently, by maintaining quality and reducing this wastage, a greater yield can be sold, thus benefitting the processor from applying the good housekeeping CPS.

Another way of reducing waste and maintaining product quality is using expiry dates. Although seafood expiry dates are set according to the age of the product and do not take into account storage temperature and initial bacterial count, they can be modelled according to storage conditions. Therefore, a model for dynamic expiry dates including storage conditions and bacterial counts can estimate and reduce losses. One study noted a reduction in losses from 17.13 % to 3.79 % (Tromp et al., 2012). Freezing reduces wastage if fish sales are unlikely before the dynamic expiry date (Thrane et al., 2009). Although freezing requires energy and refrigerants, adding to the environmental impact (e.g. ozone layer depletion), it also increases the percentage of sellable product, providing revenue from fish which would otherwise be lost in wastage (Thrane et al., 2009). By using expiry dates, seafood can then be frozen, extending the period in which to sell the product and minimise wastage using a good housekeeping CPS.

Processing may include filleting fish and disposing of other seafood waste, and using this waste to create a by-product may increase resource efficiency and profits. Processed seafood by-products can be used for fish feed (Gunasekera et al., 2002), bait (Svanes et al., 2011), pet food (Thrane et al., 2009), liquid fertiliser (Dao and Kim, 2011) and a source of lactic acid for plastic production (Gao et al., 2006). Edible products including fish sauce (Shih et al., 2003), fish oil (Garcia-Sanda et al., 2003; Thrane et al., 2009; Wu and Bechtel, 2008) and calcium (Iribarren et al., 2010a) can also be produced from processing fish waste. These by-products are an example of the waste recycling CPS.

4.5. Storage

The storage of fish causes potential environmental impacts such as global warming, ozone depletion and solid waste. Fish can be frozen, refrigerated, kept on ice or super chilled (frozen at -2 °C).

Super chilling reduces the temperature of the fish or fillet to -1 to -4 ° C, reducing the need for ice (Claussen et al., 2011) and slowing biochemical changes, without causing the structural changes of freezing (Gallart-Jornet et al., 2007). By reducing the ageing process, super chilling for nine days gave the equivalent quality of a fish stored on ice for two days (Gallart-Jornet et al., 2007) but did not differ in quality after four days with fish stored on ice (Erikson et al., 2011). An LCA study found super chilling uses less power than freezing and ice production (Winther et al., 2009), is more efficient and a “technological modification” CPS.

Storage space can be used more efficiently, particularly in a refrigerator or freezer thus reducing the energy and refrigerants required. Freezing fish does not require ice, thus increasing the quantity of product to fit in the same space (Winther et al., 2009). However, freezing the product and keeping it frozen throughout its life cycle uses similar energy consumption to ice production (Winther et al., 2009), thus creating similar emissions. Space can also be better utilised by removing the fish heads and tails (Claussen et al., 2011; Thrane et al., 2009), again, increasing the proportion of edible product in the storage space available. By reducing the need for ice, or storing a waste product, the quantity of refrigeration gases per kg of edible product decreases, thus creating a good housekeeping CPS.

The refrigerant used makes a difference in the global warming potential and ozone layer depletion over time. Blowers and Lownsbury (2010) tested three different refrigerants for a

10 tonne freezer and found the chlorofluorocarbon gas R-12 released less carbon dioxide equivalents than the hydrofluorocarbon R-134a and the hydrofluoroether HFE-143 m. Therefore, modifying the refrigerant required may reduce the carbon dioxide equivalent emissions released. Svanes et al. (2011) and Winther et al. (2009) also found replacing the refrigerator lowered refrigeration gas leakage, resulting in less waste and hence, ozone layer destruction. Another study found that the refrigerator leaked 19.2 % on a boat and recommended changing the coolants to R22 or R404a to reduce the greenhouse gases emitted (Vázquez-Rowe et al., 2013). Consequently, modifying the equipment to use a low impact refrigerant is an example of a technology modification CPS.

Maintaining quality within the processing environment can also minimise drip loss waste. Drip loss refers to the separation of the product from its’ liquid, mainly protein and water from natural processes (Fischer, 2007). Managing the handling and storage of the product reduces this and maintains the final yield sold. There are several different methods of reducing the drip loss including storing the fish in a slurry and increasing humidity in the cabinet or storage area. By using a slurry the fish did not dry out, but absorbed 2.5 % weight in four days in comparison to losing 2 % when stored in ice for the equivalent time (Erikson et al., 2011). Thus, the environmental impact will reduce per kg if the product gains weight over time in an ice slurry. However, fish is often stored in a cabinet when on display for customers where the cooling system dries the fish. By increasing the humidity in the storage cabinet, the fish can remain at the same temperature without losing liquid, thus increasing the final yield (Brown et al., 2004). Either way, by selecting a method to maintain the product’s quality and final weight is another example of a good housekeeping CPS.

4.6. Retail

Once the fish arrives in the retail outlet, it is stored in a refrigerated display cabinet until sale, when it is packaged for the consumer. Consequently, at this stage of the supply chain the product temperature and the final packaging influences the environmental impact.

One strategy in retail is to maintain the product temperature in the display cabinet. Opening the display cabinet doors continually throughout the day leads to temperature changes affecting the quality of the fish. Consequently, Laguerre et al. (2012) recommends using an air curtain to retain the cabinet temperature when the door is open. An air curtain is a stream of chilled air streaming down the entrance to the cabinet, providing a barrier and preventing outside heat entering the cabinet (James and James, 2002). Hence, temperature can be maintained throughout without the cabinet straining, conserving energy using a good housekeeping CPS.

Another strategy in retail outlets is to use packaging resources efficiently. In a standard shopping basket, the local market had a higher plastic bag consumption per sale than the hypermarket (supermarket combined with a department store) (Sanyé et al., 2012). However, the hypermarket was found to use packaging as a marketing tool and used 2.5 times the weight of the local market's plastic bag consumption (Sanyé et al., 2012). For that reason, retail outlets tend to over package, causing wastage. Planning packaging systems using minimum resources is an example of product modification CPS.

Retailers are also reacting to outside pressure for 'clean and green' products by requiring their suppliers to verify that the food they purchase is safe and, increasingly, produced in an environmentally sustainable manner (Newton, 2007). This not only influences fishermen in the upstream, but also the food processors in the downstream supply-chain to reduce their ecological footprints. Thus retailers have and use the power to influence the rest of the supply chain

CPS applied in the retail sector include maintaining product temperature and using packaging resources effectively.

5. Whole supply chain assessment and management

A whole of chain approach may both broaden the scope of CPS and increase their effectiveness. Information from the entire chain provides precise data identifying environmental improvement opportunities (Erol et al., 2011). A review by Wognum et al. (2011) agrees that mitigation strategies used in one stage of the supply chain results in costs filtering through to subsequent partners along the chain. Hence, the succeeding facilities have the power to either enhance or detract from the cleaner production practices. Clift and Wright (2000) identified the majority of environmental opportunities are currently gained from the primary resource extractor (e.g. the harvesters or aquaculture facilities). Therefore, to reduce the environmental burden on the primary producers, Clift and Wright (2000) recommend recycling resources. For example, if the fish capture has the highest environmental impact, the responsibility of reducing the impact also falls to the processor and retailer to recycle waste products, ensuring resource efficiency.

Lozano (2007) applied the Nash Equilibrium Theory to supply chains, suggesting each chain participant makes the best decision, according to their own set of parameters. Thus, without a supply chain management tool, the consequences of individual decisions to the whole of chain are not considered. If one company chooses to use CPS without considering the implications to others within their chain, their decision may have negative implications to industries both up and down the supply chain. Clearly environmental and efficiency measures are more successful when supply chains collaborate. Cooperation throughout the chain is vital not only to get the greatest profit from the least amount of resources, but also to provide access to opportunities that may otherwise go unnoticed.

In order to become more environmentally sustainable, fishermen may need to use inputs (e.g. feed) with lower ecological footprints, which in turn places additional pressures on the ‘up stream’ supply chain to adopt measures for reducing environmental impacts (Biswas et al., 2011). This is necessary to have an effective supply chain partnership that reduces environmental impact from the whole chain. Firstly, the strategies within the supply chain must benefit every partner involved and support each sector’s corporate strategies to ensure and maintain interest and support (Walker, 2012). Secondly, to keep the strategies effective and evolving, effective communication within the chain is paramount (Walker, 2012). With effective communication and aligned goals, the seafood industry partners would have the capacity to create a supply chain management plan to increase resource efficiency.

General supply chain models are available, but few are specific to fisheries. For example, working as a general whole supply chain has been modelled to: create competitive advantage (Li et al., 2006); facilitate better decision making (Lozano, 2007); increase investment (Bose and Pal, 2012; Erol et al., 2011) and profit (Singer and Donoso, 2008); improve exports (Costantini and Mazzanti, 2012); increase social acceptability (Costantini and Mazzanti, 2012); and increase efficiency (Cao and Zhang, 2011). Increasing efficiency has the potential to reduce overall costs, and to utilise resources to produce a larger quantity of output, which will reduce the environmental impact per kg of fish.

One reason for the few studies is the reluctance of partners to participate in whole of chain studies. The process is perceived to be difficult and expensive to industry in practice (Walker et al., 2008). For example, two companies may be competitors with one product, wanting to keep their practices confidential whilst also acting as supplier and customer for a different product. Communication about practices and opportunities between competitors is uncommon, only applying strategies specific to their direct processes. Therefore, the environmental benefits of whole supply chain collaboration need to be demonstrated through a proven theoretical framework.

6. Discussion

To consider environmental supply chain management in seafood, all sections of the supply chain need to work together to create viable strategies. Although Winther et al. (2009) and Ellingsen et al. (2009) covered capture and production, neither followed through to retail. Furthermore, the LCAs have only been applied to capture, transport and processing to assess environmental impacts, but little research has been found in possible mitigation strategies in the retail sector. However, LCA provides a strong basis for targeting cleaner production initiatives in, for instance, an 'eco-fish' supply chain. LCA is a useful tool to measure the environmental impact and highlight areas throughout the supply chain where CPS can be implemented.

Firstly, no supply chain stage works entirely on its own, but works interchangeably with both upstream and downstream partners. For example, an aquaculture facility not only supplies processing and retail outlets, but also relies on other farms and wild capture for fish used in feed production. If the aquaculture facility employs CPS, but the upstream processes do not, then any environmental impact reduction from the aquaculture facility is nullified by the upstream partner's emissions. Instead, the recommendation is that each company, regardless of the supply chain position, should instead source their suppliers from companies incorporating CPS with reduced environmental footprints, starting a supply chain movement.

The relationship between each supply chain stage is important when it comes to interpreting environmental research in the seafood supply chain. For example, a transport only focus looking at the distances travelled and the transport mode, using food miles as a standardised measure, is another narrow view of seafood environmental impact. This is because measuring food miles does not account for the environmental impact of processing, capture and retail. If a product has a high environmental impact in transport, it does not imply a similar result from capture or aquaculture, processing, and retail.

Secondly, by modifying a process in one supply chain stage would reduce environmental impact in another stage of the supply chain. For example, planning the storage method from the beginning of the supply chain can help minimise wastage. This would result in maximising storage space and reducing the energy and refrigeration gas quantity reduces per kg of sellable product. Thus, efficiency may improve if a downstream supply chain member communicated with the rest of the supply chain to influence the storage method applied. Therefore, to create maximum efficiency in both resource use and environmental impact, supply chains need to work together.

Despite studies in each sector of the seafood supply chain demonstrating CPS, there are still areas that require further work and strategy implementation to bring the whole supply chain together. Each of these individual strategies from the aquaculture, wild capture, transport, packaging and processing, storage and retail stages of the supply chain may be more effective if approached from the whole supply chain.

Whilst the studies discussed implemented CPS, many made recommendations without quantifying the effects of implementation in a commercial setting. Thus, further peer reviewed research is required to highlight the effect of costs, profits and product quality of any CPS in the seafood industry.

7. Conclusion

This review discusses and analyses previous results in identification, development and implementation of cleaner production strategies within the seafood industry. The relevant peer reviewed articles were identified from a structured keyword search and analysed by both supply chain stage (capture/aquaculture, transport, processing, storage and retail), and examination of the cleaner production strategies implemented. Results found entities along the seafood supply chain generally worked separately to improve cleaner production processes and outputs to grow their own businesses. Whilst this approach can be beneficial, it ignores broader cleaner production benefits that can be gained when applied across multiple supply chain entities. The most effective cleaner production strategies to improve environmental performance in each sector of the supply chain were identified, with the potential to reduce unnecessary handling, energy usage, storage costs and waste production. These strategies required planning the product specifications from the capture or aquaculture stages through to retail and ensuring all entities communicate. To create the greatest reduction in environmental impact, a whole of supply chain management system incorporating life cycle assessment modelling is recommended.

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9. Figures

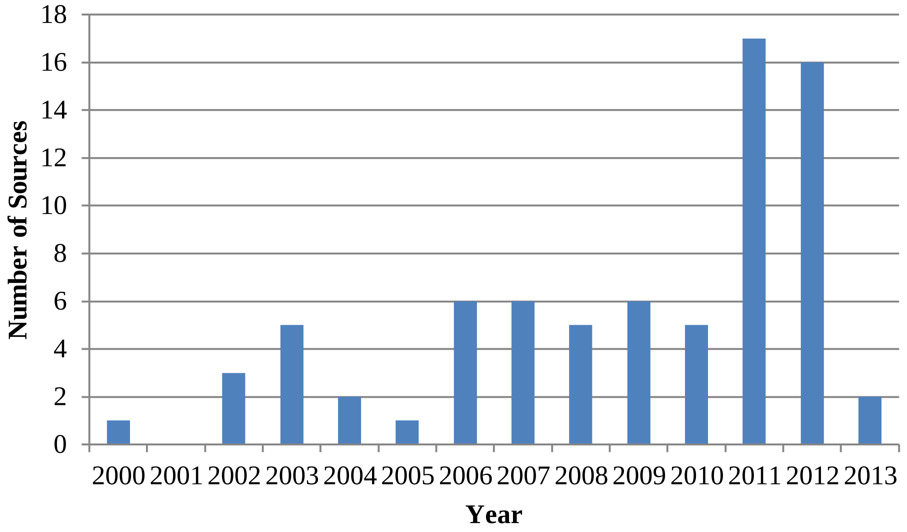

Figure 1 Distribution of sources used

List of Tables

10. Tables

Table 1 List of specific cleaner production strategies applied or recommended in the seafood supply chain

Type of Cleaner Production Strategy	Strategy	Reference
Aquaculture production		
Good housekeeping	Increased krill harvest quantity (per trip) used in feed production reduced impact of fish feed	Parker and Tyedmers (2012)
Technology modification	Using a boat fuel efficiency reduced impact of fish feed	Ziegler and Hansson (2003)
Input Substitution	Using plant resources instead of protein for feed production	Ellingsen and Aanondsen (2006)
Wild caught capture		
Technology modification	Boat structural changes increased energy efficiency in wild capture	Wakeford (2010)
Technology modification	Boat structural changes increased energy efficiency	Ziegler and Hansson (2003)
Technology modification	Boat engine choice increased energy efficiency	Sterling and Goldworthy (2007)
Technology modification	Use of GPS and colour sounder reduced fuel consumption	Marriott et al. (2011)
Technology modification	Improve selective processes to catch targeted fish and reduce catch up unwanted species by modifying fishing gear Develop methods for management decisions Involve the public to pressure industry into improving their processes	Bellido et al. (2011)
Transport		
Technology modification	Ship freight has a lower carbon footprint than air and truck freight	Tlusty and Lagueux (2009)
Technology modification	Ship freight has the lowest carbon footprint impact, followed by truck and then air freight	Vázquez-Rowe et al. (2012b)
Technology modification	Ship freight had a lower carbon footprint than air freight	Andersen (2002)
Good housekeeping	Process fish before transporting to reduce product weight, space required and refrigeration	Andersen (2002)
Good housekeeping	Process fish before transporting to reduce product weight, space required and refrigeration	Bezama et al. (2012)
Processing and Packaging		
Good housekeeping	Packaging prevented drip loss of fillets	Williams and Wikström (2011)
Product modification	Modified atmosphere packaging used less power than thermal pasteurisation and high pressure processing	Pardo and Zufía (2012)
Input substitution	Used plastic bags instead of tinplate cans to reduce weight of the packaging wastage	Hospido et al. (2006)
	Cleaner production agreements resulted in	Bezama et al. (2012)
Good housekeeping	Reduction in refrigeration gases,	
Recycling waste	Recycled wastewater	
Good housekeeping	Implementation of machinery best practice, maintenance and preventative measures	
Good housekeeping	Quality control costs reduced over time using HACCP	Lupin et al. (2010)
Good housekeeping	Quality of raw materials influences labour and costs	Zugarramurdi et al. (2004)
Good housekeeping	As quality increases, failure and costs decreases	Zugarramurdi et al. (2007)
Good housekeeping	Ice slurry storage improved quality, microbiology and reduced drip loss	Erikson et al. (2011)
Good housekeeping	Maintaining humidity during retail display prevents drip loss	Brown et al. (2004).
Good housekeeping	Expiry date management, promotes sales before aging defects occur	Tromp et al. (2012)
Good housekeeping	Freezing reduced aging of unsold fish	Thrane et al. (2009)
Recycling waste	Fish waste used for feed	Gunasekera et al. (2002)
Recycling waste	Fish waste used as bait	Svanes et al. (2011)
Recycling waste	Fish waste used for pet food	Thrane et al. (2009)
Recycling waste	Fish waste used for liquid fertiliser	Dao and Kim (2011)
Recycling waste	Fish waste fermented for the production of biodegradable plastics	Gao et al. (2006)
Recycling waste	Fish waste used for fish sauce	Shih et al. (2003)
Recycling waste	Oil extracted from wastewater after canning fish	Garcia-Sanda et al. (2003)
Recycling waste	Oil is extracted from wastewater after canning fish	Thrane et al. (2009)
Recycling waste	Oil extracted from pink salmon heads and viscera	Wu and Bechtel (2008)
Recycling waste	Calcium extracted from mussel shells	Iribarren et al. (2010a)

Storage		
Good housekeeping	Super chilling fish increases volume on truck as ice is not needed	Claussen et al. (2011)
Good housekeeping	Super chilling slows aging without freezing	Gallart-Jornet et al. (2007)
Good housekeeping	Super chilling uses less power than freezing and ice production	Winther et al. (2009)
Technology modification	Modified the refrigeration system to use a refrigerant with less global warming potential	Blowers and Lownsbury (2010)
Technology modification	Refrigerator maintenance reduced leakage of the refrigeration gas	Svanes et al. (2011)
Technology modification	Underperforming refrigerator replacement reduced leakage of the refrigeration gases including chlorofluorocarbons	Winther et al. (2009)
Technology modification and Input substitution	Changing the coolants to R22 or R404a reduced the greenhouse gases emitted	Vázquez-Rowe et al. (2013)
Product modification	Space is increased for the edible portion of the fish by removal of heads and tails.	Claussen et al. (2011)
Product modification	Space is increased for the edible portion of the fish by removal of heads and tails.	Thrane et al. (2009)
Retail		
Technology modification	An air curtain maintains temperature of display cabinet where fish fillets are stored during retail opening hours	Laguerre et al. (2012)
Technology modification	An air curtain maintains temperature of display cabinet where fish fillets are stored during retail opening hours	James and James (2002)
Product modification	Reduce packaging in retail market	Sanyé et al. (2012)