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From Sea to Table: Recommendations for Tracing Seafood

2010 Group Project

Jamie Gibbon
Connor Hastings
Tucker Hirsch
Kristen Hislop
Eric Stevens

Faculty Advisors:
Hunter Lenihan
John Melack

Client:
Monterey Bay Aquarium's Sustainable Seafood Initiative

From Sea to Table: Recommendations for Tracing Seafood

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Jamie Gibbon

Connor Hastings

Tucker Hirsch

Kristen Hislop

Eric Stevens

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The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

Hunter Lenihan

John Melack

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Abstract

The seafood industry currently lacks a standardized, widespread tracing method to easily track seafood products as they move through the chain of custody. With global overfishing leading to declining fish stocks around the world, it is vital for seafood providers to be able to credibly identify products that come from well-managed sustainable fisheries that target abundant species and fish or farm in environmentally responsible ways. As part of their effort to promote the sale of sustainable seafood, Monterey Bay Aquarium has created partnerships with members of the seafood industry throughout the United States. These partnerships encourage members of the supply chain to identify the source and trace the movements of the seafood products they purchase. This project provides a set of recommendations for a verifiable tracing system that would meet the needs of a wide variety of these industry members. We developed a tiered approach that includes recommendations for immediate implementation, as well as future steps to be taken once the initial system is established. Online Reporting can initially be used alone and then later paired with Product Tagging and Third Party Verification to produce a tracing system that is effective, comprehensive, and verifiable, and will meet the needs of Monterey Bay Aquarium and its partners.

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Executive Summary

The worldwide demand for seafood has led to industrialized fishing on a scale that has severely depleted fish stocks and has negatively impacted the health of marine ecosystems. As fishermen exploit fisheries and "fish down the food chain", the trophic levels of fish landings are changing dramatically, leading to a decrease in the number of important predatory species. Overfishing is costly, and altered fish landings have created economic hardships for fishermen worldwide. In addition, illegal, unreported, and unregulated (IUU) catches threaten the sustainability of many sensitive fisheries. Increased tracing of seafood products has the potential to help alleviate these problems by giving suppliers and consumers relevant information that allows them to make sustainable choices when purchasing seafood.

The seafood industry currently lacks a standardized, widespread method to easily trace seafood products that they purchase along the chain of custody. With global overfishing leading to declining fish stocks around the world, it is vital for seafood providers to have the ability to identify and buy products from sustainable fisheries that are well managed, target abundant species, and fish or farm in environmentally responsible ways. A tracing system that incorporates online inventory reporting or both online inventory reporting and physical product tagging, augmented by independent supply chain verification will give companies and consumers the information they need to make sustainable seafood choices.

Our client, Monterey Bay Aquarium, formed its Seafood Watch program in 1999 to promote the purchase of sustainable seafood and encourage the protection of the ocean ecosystem. Seafood Watch forms partnerships with members of the seafood industry in order to increase the availability of sustainable seafood. In 2009, the Aquarium entered into an agreement with Santa Monica Seafood, the largest seafood distributor in the southwestern United States. As part of this partnership, Santa Monica Seafood agreed to increase the overall percentage of sustainable seafood products that they sell, as designated "Best Choices" and "Good Alternatives" by Monterey Bay Aquarium. In order to achieve this goal, Santa Monica Seafood needs more information on the source of many of their products. They turned to us to produce a set of recommendations for a verifiable tracing system that would allow Santa Monica Seafood to confidently identify the source and supply chain movements of the seafood products that they buy.

We began this project with an extensive literature review consisting of three major areas. The first area analyzes the strengths and weaknesses of current available tracing systems; the second area examines how tracing is being used for other products, including shellfish, certified forest products, and organic products; and the third area provides an overview of the general atmosphere of tracing which includes

overfishing, seafood fraud, aquaculture, country of origin labeling, eco-labeled seafood, consumer response to sustainable seafood, and economic incentives for tracing. This review demonstrated that there is a need and, in many cases, a demand for a comprehensive tracing system. It also suggests that a tracing system has the potential to close many gaps in current seafood legislation and non-governmental efforts. The literature shows that a comprehensive tracing system must address a wide scope of problems to be successful – from illegal fishing practices on the high seas, to legal and common practices that are environmentally degrading in farmed fishing industries, to areas both of conflict and consensus between consumers and suppliers of seafood. A tracing system must also satisfy a wide array of needs from small, local fisheries to national requirements to an industry that spans international markets. Additionally, tracing seafood must be economically feasible in order to gain acceptance.

The next step of this project consisted of direct communications with companies providing various forms of product tracing services. We decided to focus on three tracing options that are currently commercially available and have the potential to provide full chain of custody tracing and verification: online reporting, third party verification, and product tagging. The benefits of online reporting are that all the information for the chain of custody for a seafood product can be stored in one central location and that these systems keep extensive records on both internal and external tracing for a supply chain, and can incorporate information from numerous companies. However concerns include information security and the accuracy of self-reported information. Additionally, the web-based system can only trace products throughout the entire supply chain if all companies subscribe to the online tracing service. Product tagging has the benefit that a seafood item's source and handling information can permanently accompany it as it makes its way to the consumer. However, there is concern about the ability to trace a tagged product once it has been processed or partitioned. Third party verification allows for comprehensive knowledge of the supply chain. However, third party verification systems do not provide the end user with comprehensive information on the product movement over the entire supply chain, leading to loss of information on the product.

In order to uncover the industry perceptions of and concerns about implementing a tracing system, we contacted and interviewed a variety of members of the seafood industry, including fishermen, buyers, brokers, distributors, retailers, and auditors. We combined these industry perceptions with general cost information for each of the three types of tracing systems. This analysis revealed that for several characteristics there was a consensus of opinion. However, with some characteristics there were differing opinions between industry members who bought and sold high volume products such as farmed salmon and those who dealt with low volume products, such as yellowfin tuna. Opinions were most varied when asked about the effect of tracing on product speed and on the overall acceptability of tracing by the seafood industry. This dichotomy should be taken into consideration when analyzing tracing needs and

concerns. Another relevant finding from the interviews revealed that industry members often have misperceptions about tracing systems, specifically the cost of different tracing systems and logistics behind implementation. Additionally, the majority of those interviewed were only aware of MSC for third party audits, which can be detrimental since the MSC certification is not applicable to all fisheries.

After speaking with industry stakeholders, we received a variety of responses to the questions surrounding the cost of implementing different tracing systems. When we began to probe for information regarding costs associated with the systems, we found many dead ends. The price tag for a tracing system is often confidential between the tracing company and the fishery or other members of the chain of custody. Where costs were not confidential, information was varied, depending on the source, and often the primary contact did not wish to disclose that information to us. However, we were able to gather a substantial amount of information about the costs of tagging, online reporting, and third party verification and make three main findings. First, the cost to implement any of the tracing systems is not uniform and varies depending on the fishery, the product, and the practices therein. For example, tagging ranges from $.03 to $1.00 per tag, depending on the type of tag. To implement and use a tagging system, costs will depend on how many tags are used, what technology is used to read the information on the tag, and if the tags can be re-used. Second, we found that online reporting is the least costly system to implement initially, while third party verification is the most costly. Tagging may be the least costly system in the long run, while third party verification still has the highest costs associated with it even after the initial implementation. Lastly, the cost for implementing any tracing system may be shared by the members of the chain of custody and does not need to be distributed uniformly. Overall, the information contained in this report regarding the costs to implement tracing systems fairly represents costs, but those numbers can still vary and are situation dependent.

Using the information from our literature review and stakeholder interviews, we created recommendations for the implementation of tracing by the seafood industry. We developed a tiered approach that includes two options for immediate implementation as well as steps to be taken once the initial system is established. The first option uses online reporting, the most cost effective tracing system and the only system that allows all of the supply chain information to be centrally stored in one location. The second option should be used for supply chains where members at the head of the supply chain do not have access to the necessary technology for online reporting. In this option, product tagging can be used to fill the gaps where online reporting is not feasible. Tags record catch method and location until the product reaches a point in the supply chain where data can be entered online. Following the establishment of either of these two options, third party verification can be added to verify that these tracing systems are in place and being used properly. Tags record origin and catch method until the product reaches a point in the supply chain where data can be entered online. Following the establishment of either of these two options,

Third Party Verification can be added to confirm that the information provided throughout the supply chain is accurate and complete.

Finally we conducted an examination of the benefits of using our recommended system as it would be applied to three case study seafood products. These products included farmed salmon, yellowfin tuna, and wild caught scallops. Tracing farmed salmon using online reporting paired with third party verification would allow salmon farms to differentiate themselves by allowing supply chain members to highlight bacteria free facilities, sustainability of aquafeed used, and less ecologically harmful farming practices. Product tagging and online reporting paired with third party verification of scallops would increase supply chain members' confidence in the products by diminishing adulteration and product switching concerns. Product tagging is already used with scallops in order to determine from which boat they were harvested; this information could easily be entered into an online database once purchased. Distinguishing between dredged, on-bottom farmed scallops and hand harvested, off-bottom farmed scallops would allow buyers and consumers to make a choice with the environment and sustainability in mind. Product tagging and online reporting paired with third party verification of yellowfin tuna would facilitate a verifiable way to determine the catch origin and the type of catch method used. Products could be tagged when caught, then entered into an online reporting system and finally verified by a third party. This system would ensure a high quality and legally caught yellowfin tuna.

Project Significance

The current political environment is favorable for fishing industries and their partners to implement a chain of custody tracing system; the EU recently mandated documentation to record the movements of international seafood products they purchase, and other countries and organizations are drafting standards and legislation addressing tracing. However, to our knowledge, comprehensive analyses of current, available tracing systems and recommendations on how they can be implemented are not widely available to the seafood industry.

Our report offers an analysis of the current state of seafood tracing technology and programs. This information will be invaluable as demand grows for an effective, streamlined tracing system that supports the promotion of sustainable seafood. Quantifying the strengths and weaknesses of economic costs and benefits of current systems, as well as identifying the challenges and limitations of existing tracing technology, will provide much needed information to a wide variety of groups. Environmental non-governmental organizations will be able to use this information to more effectively encourage partnerships with the seafood industry by highlighting the benefits of tracing systems and making their adoption more appealing to businesses throughout the seafood supply chain. Businesses that provide tracing systems may be able to expand into areas where gaps currently exist and fill growing demands while augmenting their business. Finally, policy makers will have the information they need to set up an effective regulatory framework, delegate responsibility to appropriate agencies, and increase the adoption of seafood tracing by creating an inclusive, efficient, enforceable, and attractive system.

Objectives

The Aquarium's Sustainable Seafood Initiative believes that a widely supported and effective seafood tracing system is a necessary component in the efforts to promote environmentally responsible fisheries and fight industry fraud. While several private organizations have created voluntary tracing systems, no standardized system for all products exists. By working with our client, their partner Santa Monica Seafood, and a wide variety of stakeholders within the seafood industry, we provided a detailed overview of existing seafood tracing systems, an analysis of costs, challenges, and benefits of these systems, and provided the Aquarium's Sustainable Seafood Initiative with a variety of recommendations for implementing seafood tracing with their partners. Furthermore, we examined what a tiered seafood tracing system may look like, and how various sectors of the seafood industry could efficiently and successfully adopt such a system. Specifically, we:

1) Researched available tracing systems and analyzed their strengths and weaknesses.
2) Created an informational matrix that summarized the opinions and attitudes of industry members that were collected through interviews.
3) Created general recommendations for implementing a tiered tracing system that could be used by a wide range of industry members.
4) Examined how our recommended tracing system would be applied to three specific seafood case studies:
    I. Farmed salmon from many international locations, including Chile, Norway, Canada, and the United States.
    II. Wild caught scallops from New Bedford, Massachusetts.
    III. Wild caught tuna from Fiji and other locations in the Pacific.

Methods

We began our project by conducting a literature review of background information pertinent to seafood tracing. The literature review allowed us to define the issues that a seafood tracing system should address, gain an understanding of the strengths and weaknesses of existing tracing options, and become informed on the mechanisms that allow these systems to work. Part of this research involved direct communications with companies providing various forms of product tracing services, including TraceRegister, TraceTracker, the Marine Stewardship Council and Ketchum Manufacturing. We also contacted and interviewed 19 individuals, representing a wide variety of seafood industry members, including fishermen, buyers, brokers, distributors, and retailers. We collected their opinions and attitudes on the characteristics of several tracing systems and summarized these results in an informational matrix. These interviews provided insight into the perspectives and priorities of different members of the supply chain and illustrated how a product tracing system would fit into the framework of different seafood supply chains.

Using the data collected we identified the strengths and weaknesses of three currently available tracing systems and developed recommendations for a tiered tracing approach that our client can recommend to its partners. Finally we explained how our recommended system could provide benefits to three case study seafood products.

Background

Literature Review

This section is an overview of problems that can be addressed through tracing, other industries that use tracing techniques, current requirements for tracing seafood products, as well as incentives for tracing. This research has helped us establish a baseline understanding of tracing systems that currently exist, both in the seafood industry and outside of it, and how we might manipulate current tracing schemes and address their shortcomings to develop an effective tracing system.

Overfishing

The worldwide demand for seafood has led to industrialized fishing on a substantial scale that has severely depleted fish stocks and has negatively impacted the health of marine ecosystems. As fisheries are exploited, the trophic levels of fish landings have changed dramatically, indicating a decrease in the biomass of important predatory species. Overfishing is costly, and altered fish landings have created economic hardships for fishermen worldwide. In addition, illegal, unreported, and unregulated (IUU) catches threaten the sustainability of many sensitive fisheries.

The motivation to trace seafood stems from the need to know a product's origin and catch method. This is necessary in order to reduce the amount of IUU catches and allow distributors to provide important product data to consumers. Many conservationists and managers believe that tracing is one way to help solve the problem of overfishing by increasing transparency throughout the industry.

A number of incentives, such as open-access policies and subsidies, have created a "race to fish" mentality among fishermen that has contributed to a global decrease in fisheries' stock sizes (Garcia et al. 1997). These incentives create little motivation for fishermen to fish at sustainable levels, as their competitors are likely to fish more than their share of the stock if given the opportunity. Illegal and destructive fishing practices exacerbate the problem of depleted fish stocks, especially in international waters where monitoring and regulation are difficult to enforce (Sumaila, Alder, and Keith 2006).

The effects of unsustainable fishing have led to changes in the trophic structure of fish food webs (Pauly et al. 1998). The biomass of higher trophic levels of fish has decreased significantly since 1900 (Christensen et al. 2003), and in response to this decline fish landings have shifted away from larger predators and have been replaced by smaller planktivorous fish and invertebrates (Pauly et al. 1998). The mean trophic level of fish caught has declined globally at roughly 0.1 levels per decade, without a

notable increase in total fish landings (Pauly et al. 1998). Additionally, Hutchings & Reynolds report 55 fish species have been removed from parts of their global ranges and overfishing has caused the collapse of numerous fisheries, such as the Canadian cod fishery that has lost 99.9% of its cod population (Hutchings and Reynolds 2004). Overfishing has shortened fishing seasons as stocks are unable to recover from unsustainable harvest rates between seasons (Hutchings and Reynolds 2004; Schmidt 1993). Catch quotas in Europe have been substantially reduced, putting many fishermen out of work, and the Food and Agriculture Organization estimated that overfishing costs the world 15 to 30 billion dollars per year (Schmidt 1993). This overexploitation has been traced back to early colonial times (Jackson et al. 2001).

Destructive fishing methods also cause ecological harm. Jackson et al. (2001) show that historical ocean records indicate overfishing as the catalyst for marine species decline in a variety of habitats including kelp forests, coral reefs, seagrass beds, estuaries, and offshore benthic communities. Overfishing often facilitates eutrophication, outbreaks of disease, and the introduction of non-native species. Some practices, such as trawling and longline fishing, generate bycatch and negatively affect many species (Lewison, Sloan Freeman, and Crowder 2004). For example, these fishing methods have led to an 80-95% decrease in loggerhead and leatherback turtle populations in the Pacific in the last 20 years. The use of explosives and toxins by fishermen can decimate coral reefs, as has occurred in the Philippines where catch rates and biological diversity have both declined (Rubec 1988).

IUU fishing has also severely depleted fish stocks. Sumaila et al. report that unreported fishing leads to inaccurate estimations of fish stocks, leading managers to misjudge the health of populations (Sumaila, Alder, and Keith 2006). The Patagonian toothfish is now endangered as a result of illegal fishing in the form of inaccurate catch data. IUU, by its nature, is very hard to quantify. However, the US Food and Agriculture Organization estimates that 30% of total catches are IUU and in some fisheries account for three times the permitted catch level (Doulman 2000). IUU fishing is perpetrated by both domestic and international fishing vessels (Doulman 2000). Excess fleet capacity, poor fisheries management and ineffective monitoring are factors that encourage IUU fishing (OECD 2004). The expected economic benefits of IUU fishing outweigh the costs in most cases, as there are insufficient penalties and regulations in place. Until those perverse economic incentives are addressed, fishermen's motivation to harvest seafood in an unsustainable manner will persist (Sumaila, Alder, and Keith 2006).

Seafood Fraud

Fraudulent practices, such as the mislabeling and adulteration of products, are problematic throughout the seafood industry. These practices compound the problems associated with overfishing in many ways, such as labeling unsustainable products in a way that misleads consumers to believe they are sustainable choices. The complex nature of the chain of custody for seafood products is vulnerable to fraud at points, and accurate information can be lost as seafood changes hands between the boat and the point of final sale.

Like IUU fishing, seafood fraud is likely to continue unless management practices change. Tracing would allow distributors to examine the entire chain of custody, and potentially provide the tool to close those gaps in the system where fraud occurs.

Increasing resource scarcity, weak legislation and enforcement of laws, as well as the hope for greater profits has contributed to the mislabeling of seafood (Jacquet and Pauly 2008). Legally, suppliers can label fish species with Food and Drug Administration-approved names that make the products more marketable and appealing to consumers (Food and Drug Administration 2009), such as calling rockfish "red snapper". However, the use of non-approved names is illegal. One study estimated that 77% of fish labeled and sold as red snapper were not a species approved as a "red snapper species of fish" (Fox 2008). Additionally, a similar study found that six out of eight fish labeled as wild salmon were farm raised (Fox 2008). In an experiment performed by the Barcode of Life Database, one sample labeled as red snapper was found through genetic analysis to be Acadian redfish, a species listed as endangered (Schwartz 2008). Thus, not only are consumers not receiving the correct product, but may be unknowingly purchasing fish from unsustainable fisheries.

Seafood imported into the US changes hands many times, increasing the opportunity for fraud. The Food and Drug Administration inspects less than 1% of imported fish and some mandatory labeling requirement for fish ends once the product passes customs (Fox 2008). A majority of the mislabeling occurs at a point in the supply chain in which fish is no longer definitively identifiable because many of the unique characteristics of the fish, such as markings and size, are no longer evident after processing (Marko et al. 2004). Logan et al. show that 80% of fish are correctly labeled by species at landing, but information is lost between the dock and the point of sale to seafood buyers (Logan et al. 2008). The burden to substantiate sustainability claims falls on the producer to maintain adequate records (National Grocers Association 2005). However, with many steps in the supply chain, this is difficult to accomplish.

Product switching is also prominent in many sectors of the seafood industry, both by false species labeling and incorrect geographic information labeling (Buck 2007). Product switching is more prominent with highly processed seafood products because the product can often no longer be visibly identified (Marko et al. 2004). Tracing can add an additional hurdle, making it more difficult for a company to receive one type of product and sell it under a different name without detection. This information will also potentially decrease product adulteration, as members of the chain of custody will have information available on the quantity of seafood product that is inputted into, and the quantity that is outputted from, a seafood processor (Ratcliff and Boddington 2009).

The Food and Drug Administration oversees compliance with the Food, Drug and Cosmetic Act of 1938, the primary federal law addressing the mislabeling of seafood (Buck 2007). The Food and Drug Administration's resources committed to combating seafood fraud are limited and enforcement is minimal (Buck 2007). Seafood fraud is thus a major problem for the sustainability of the world's fisheries because consumers may be willing to make sustainable seafood choices, but the power they wield in their buying habits is limited by the lack of validity of many seafood labels. In addition to the biological risks associated with consumer fraud are economic consequences. Consumers often pay high prices for fish thought to be of a certain caliber, which have been replaced somewhere along the supply chain by less desirable species (Fox 2008). Without consumer confidence in the validity of seafood labels, a sustainable seafood certification program will have limited success. Implementing a seafood tracing system that holds all members of the supply chain accountable may foster consumer confidence.

Aquaculture

Seafood is an important protein source for human consumption, and with a growing global population, the demand on fisheries is increasing. Aquaculture, or fish farming, has the potential to alleviate the pressure on wild fisheries, but the industry faces many challenges. Aquaculture puts pressure on wild populations in a variety of ways. These impacts must be addressed in order for aquaculture to successfully assist with the problem of overfishing.

All aquaculture practices are not equally detrimental to the environment. In order to differentiate the "green" products from other farms, a trusted method must provide customers with information on the products they purchase. Tracing would allow environmentally responsible distributors and retailers to differentiate their products.

One of our case studies, farmed salmon, is an aquaculture product that is part of a $450 million aquaculture industry in both the US and international markets (Stokstad

2007). This industry has had significant impacts on the wild salmon industry and has many environmental and health concerns associated with its salmon farms. Such detrimental issues include increased disease and parasites affecting wild populations, decreased wild salmon populations, decreased populations of other fish species due to their use in salmon feed, and increased toxic compounds and chemicals in salmon for human consumption (EDF 2010; Krkosek et al. 2007; Owen 2008; Roach 2006). Krkosek et al. (2007) estimate that we may see a 99% decline in wild salmon populations in just four generations, or eight years. Some salmon farms have reduced risks to wild salmon populations by using closed tank systems, minimizing the potential for escapees and the introduction of parasites and disease (Monterey Bay Aquarium Salmon 2010).

Aquaculture is a rapidly growing industry, with global production more than doubling between 1985 and 2000 (Rosamond et al. 2000). By 2000, farmed fisheries made up 25% of the total human fish consumption (Naylor et al. 2000). Aquaculture is attractive partly because it provides inexpensive protein alternatives to wild products (Rosamond et al. 2000). Additionally, aquaculture is often believed to have the potential to relieve pressure on sensitive fisheries, although this is a misconception due to the necessity of using wild populations as a source of feed and stock (Rosamond et al. 2000).

For our project, we categorize the unsustainable effects of aquaculture into three categories: 1) resource competition with the natural environment, 2) addition of wastes into the surrounding environment, and 3) biological pollutants.

Resource Competition

All aquaculture practices take something from the natural environment, either biological, abiotic, or in the form of ecosystem services. Aquaculture as a whole uses a large quantity of wild fish stocks in fish feed. The ratio of wild fish biomass to farmed fish product can range from less than one-to-one to well over five-to-one (Rosamond et al. 2000). Krkosek et al. (2007) report a decrease in populations of other fish species because of the amount harvested for use in salmon feed. Aquafeed is not easily identified by species, as 81.8% of fishmeal and 55% of fish oil production is not reported at a single species level (Tacon 2005). This can make it difficult to trace the aquafeed to its original source (Tacon 2005). Farming practices can compete for ecosystem services with other local processes by requiring large amounts of natural resources and returning high quantities of waste to the environment (Beveridge, Ross, and Kelly 1994; Macintosh, Phillips, and Beveridge 1997; Naylor et al. 2000). Aquaculture farms need a source for fish – either as juveniles, eggs, or adults – and this requirement can compete with the wild-caught fishery (Macintosh, Phillips, and Beveridge 1997; Naylor et al. 2000).

Waste input

Fish in farmed systems, either inland, coastal, or nearshore, create a variety of wastes that flow into the surrounding areas. These wastes include uneaten food, fecal matter and urinary wastes that may include hormones, antibiotics, and vitamins (Beveridge, Ross, and Kelly 1994; Macintosh, Phillips, and Beveridge 1997; Wu 1995). Farmers often treat their stock and/or the water to maintain healthy populations and environments. Treatments may involve the addition of antimicrobials, parasiticides, vaccines, disinfectants, chemotherapeutants, antiseptics, and antifouling chemicals (Beveridge, Ross, and Kelly 1994; Macintosh, Phillips, and Beveridge 1997). The chemicals in the water can disrupt nutrient and energy cycling in natural systems, simplifying food webs, and decreasing biodiversity over all (Beveridge, Ross, and Kelly 1994). Farmed salmon contains higher levels of polychlorinated biphenyls (PCBs), toxic industrial compounds and chemicals than wild populations and can pose neurological health risks to fish and people (EDF 2010).

Biological pollutants

Escaped individuals from aquaculture systems can have negative impacts on the surrounding natural environment (Beveridge, Ross, and Kelly 1994; Macintosh, Phillips, and Beveridge 1997; Naylor et al. 2000). Escaped individuals interbreed and hybridize with native individuals, disturbing reproductive rates (Naylor et al. 2000). Pathogens can spread between native and non-native species, between farmed and natural conspecifics, and between farms (Naylor et al. 2000). In the farmed salmon industry, Roach and Owen (2008; 2006) report that increased disease and parasites have decreased wild salmon populations. Biological threats do not necessarily come from escaped individuals; juvenile salmon are often infected by parasitic sea lice when they pass salmon farms during migration (Owen 2008). Sea lice make it difficult for juvenile salmon to regulate their body fluids, feed on the fish's tissue, and cause stress, viral and bacterial infections, osmotic failure, and death (Krkosek et al. 2007; Stokstad 2007).

Country of Origin Labeling

Under Country of Origin Labeling legislation, many seafood products must be labeled with the name of the country from where they are sourced. However, the law includes provisions that exclude many products from these requirements. The majority of processed fish products and seafood that is not sold in grocery stores is exempt from the labeling rules.

Full chain of custody tracing could provide information on the source of products that are currently exempt from Country of Origin Labeling regulations, and provide additional information about the product that is of consumers' concern or interest.

In the US, multiple agencies are responsible for regulating seafood and assuring that the public is given information about the fish products that they buy. While the Food and Drug Administration oversees seafood imports, the US Department of Agriculture is the federal agency responsible for regulating the labeling of seafood products. The US Department of Agriculture developed and published Country of Origin Labeling rules effective for fish and shellfish on April 5, 2006 (USDA B 2009). The Country of Origin Labeling regulations lay out those products that require labels, the party responsible for providing labels, and specific information that must be included on labels (National Grocers Association 2005). While the Country of Origin Labeling program applies to a large portion of fresh seafood sold in grocery stores across the US, it also contains many loopholes that exempt seafood products from labeling requirements.

The Country of Origin Labeling requirements apply to any retailer who buys and sells fruits and vegetables valuing more than $230,000 a year (National Grocers Association 2005). This includes most grocery stores, but does not apply to fish markets and exporters, as they often do not sell produce. The rules also exempt restaurants and cafeterias, as well as salad bars and delis inside grocery stores that provide ready-to-eat meals (National Grocers Association 2005). Country of Origin Labeling mandates that all fresh or frozen fish and shellfish sold by retailers must be clearly labeled with the country of origin and the method of production (e.g. wild caught or farm raised). Wild caught fish can receive a US origin label in one of three ways: 1) if they were caught in US waters, 2) if they were caught by an American flagged vessel in international waters and processed in the US, or 3) if they were processed aboard a US flagged vessel (USDA B 2009). For farm-raised seafood to receive a US origin label, the fish must have been hatched, harvested, and processed entirely in the US (USDA B 2009). All other products must be labeled with their country of origin and any countries in which they have been processed (National Grocers Association 2005).

Many seafood products that have been significantly altered by processing, such as cooking and smoking, or have been combined with other food products, such as breading or marinating, are not subject to Country of Origin Labeling (USDA B 2009). This provision exempts a large range of products such as fish sticks, coconut shrimp, soups, stews, chowders, marinated fish fillets, sushi, and breaded shrimp. While imported food is still subject to labeling requirements under the Tariff Act of 1930, a wide range of seafood products are sold with no information on their origin (USDA A 2009).

A comprehensive tracing system providing information about a product at each stage of seafood handling as it makes its way to customers would address the lack of consumer information currently available and help fill in the gaps in existing legislation. Increasing consumer awareness and information availability may lead to increased demand and profits (see *Consumer and Retailer Attitudes and Preferences*),

while full supply chain tracing could help track the origin of foreign products that currently do not fall under the Country of Origen Labeling laws.

US Catch Documents for Exports to the EU

Recently, the EU increased it efforts to reduce the sale and transfer of illegal, unreported, and underreported seafood products into the EU by requiring catch certificates to accompany each product throughout its movement along the supply chain. New information is entered into the certificate each time the product changes hands, from the initial fishing vessel to the product's eventual importation into the EU.

This system is an example of large scale, international chain of custody documentation and tracing. It requires cooperation and partnership between countries and within fishing industries. This ambitious multi-national corroboration implies that a favorable political environment currently exists to address tracing the chain of custody for seafood products. Additionally, the strict regulations are an acknowledgement that the current systems are not sufficient for food safety or for adequate stock assessments and management. Furthermore, a successful implementation of catch documents will demonstrate the capability of fishing industries to track highly mobile products over large distances.

On January 1, 2010, the European Union (EU) implemented new legislation for IUU fishing. The legislation, (EC) No 1010/2009, is a detailed description of the rules for implementing (EC) No 1005/2008 that mandates catch documentation for seafood products imported into the EU from non-Union states (European Community Council 2008; NOAA A 2010). Legislation (EC) No 1005/2008 states:

> "The current system [prior to this legislation] applying to fishery products caught by third country fishing vessels and imported into the Community does not ensure an equivalent level of control. This weakness constitutes an important incentive for foreign operators carrying out IUU fishing to trade their products in the Community and increase the profitability of their activities. As the world's largest market for, and importer of fishery products, the community has a specific responsibility in making sure that fishery products imported into its territory do not originate from IUU fishing. A new regime should therefore be introduced to ensure a proper control of the supply chain for fishery products imported into the Community" (European Community Council 2008).

The new law also requires EU vessels exporting seafood products outside of the Union to provide catch documents to the importing countries if they request a

document (*Figure 1)*. The catch document and the information it contains must remain with the product through all stages of its handling, including catch, market, processing, and transport, and at each stage handlers add pertinent information to the document (European Community Council 2008). All members of the chain of custody share the responsibility of transferring the catch document—the exporter must request a catch document from the proper authority in their country and the importer must collect and retain the document from the exporter for three years from the date of import (NOAA A 2010).

In the United States, any exporter of wild harvested fish or fishery product, fresh or processed, must request a US Catch Document from the National Oceanic and Atmospheric Administration's (NOAA) Seafood Inspection Program for products going to the EU (NOAA B 2010). Many exporters of fish and fishery products sell one product to multiple buyers and/or sell a variety of products to a single buyer in one transaction. Under the new regulation, NOAA can grant one catch document for each transaction, simplifying the process. In the event that a portion of the exporter's product is exempt, the catch document is still required and is specific to the applicable portion of the sale (NOAA B 2010).

While the EU's new legislation is ambitious, it is still not a perfect solution to complete chain of custody tracing and presents some challenges. There are a number of products listed as exemptions in (EC) No 1005/2008, such as many freshwater, shellfish, and aquaculture products, that do not require a catch document (European Community Council 2008). The legislation only targets a reduction of illegal fishing practices, but does not address fraud or sustainability issues (Hedlund 2009). The United States has helped to ensure a smooth transition and to enable US fisheries to comply with the new EU mandate, but not all countries have been successful (Hedlund 2009). The new legislation has already negatively impacted fisheries in some countries, such as Vietnam and the Philippines, which cannot yet comply with the law (Icamina 2010; VietNamNet Bridge 2010). Vietnamese tuna sales, for example, have dropped twenty percent since implementation from postponed shipments and a decrease in contracts for export to the EU that cannot provide proper documentation (VietNamNet Bridge 2010). The US has also decided to include a third party audit as part of NOAA's compliance with the EU law, but not all countries have the ability to do the same, leaving the catch document system with little or no verification component (Hedlund 2009). The implementation and results of (EC) No 1005/2008 highlight the challenges and potential successes of chain of custody traceability: initially small, individual fisheries, especially in technologically challenged countries, may be at a disadvantage because they cannot comply with the tracing requirement. However, illegal and unsustainable practices may be phased out.

Shellfish

Shellfish products sold in the US are closely monitored through every stage of their handling, as mandated by the Food and Drug Administration's National Shellfish Sanitation Program. Thorough records are kept for every instance in which shellfish changes hands, so that the specific path to market, starting from the point of harvest, is known for all shellfish products. The extensive tagging and labeling requirements on shellfish containers enable this high level of transparency.

The effective product tracing system that is already in place for shellfish serves as a successful model that could be used to improve tracing in other seafood product supply chains. Product tagging is a key component of this model, and represents a promising tracing strategy that could be implemented in other seafood industries, allowing them to go beyond the broad and easily manipulated Country of Origin Label standard which currently regulates seafood product transparency in the US.

Shellfish is subject to stringent regulations on product tracking and handling due to the severe consumer health threat posed by contaminated products (Food and Drug Administration 2009). The Food and Drug Administration has established uniform standards for the shellfish industry through the National Shellfish Sanitation Program, which outlines requirements for each stage of the shellfish supply chain (Food and Drug Administration 2009). Under the program, harvesters may only take shellfish from legally designated growing areas and must print tags on each shellfish batch, listing the company name, harvest location, and date of harvest. The Food and Drug Administration mandates that the tags must accompany the shellfish during shipping and storage, and handlers must follow specific sanitation precautions. Large bulk sales of shellfish require the harvester or dealer to submit a transaction record for the product prior to sale. Dealers of shellfish are banned from selling any products that come from shipments which: 1) are not provided by a licensed harvester or dealer, 2) have not met handling/storage standards, or 3) come from an unidentifiable source (Food and Drug Administration 2009). State government officials routinely inspect shellfish dealers for compliance with handling, shipping, and record-keeping procedures (Connecticut Department of Agriculture 2010). If inspectors find a shellfish wholesaler in non-compliance, the wholesaler is normally given a warning and advised on the importance of following procedure. However, wholesalers with repeated or severe violations may have their permit to sell shellfish suspended or revoked (US Food and Drug Administration 2010)

The shellfish industry and its associated regulations rely heavily on the ability to trace products through the chain of custody. Public outbreaks of shellfish-borne illnesses have declined significantly since the early 20th century (New York State Department

of Environmental Conservation 2010). After contaminated shellfish from New York waters sickened more than a thousand people in the 1920's, extensive monitoring of the shellfish trade was enacted to help the industry regain the trust of consumers. There are now quick and effective protocols to follow if a shellfish-borne illness is detected. Shellfish dealers' records can be examined to identify the original shipper of the contaminated product, as well as its harvester and harvest area. Other shellfish products shipped from the same location can be found and destroyed to prevent the purchase of contaminated products. The waters where shellfish grow are sampled each year to ensure they meet water quality standards to allow for the harvest of uncontaminated shellfish. If water quality standards are not met, the growing area is closed to harvesters. In the case of New York, 17% of the state's shellfish growing area (roughly 200,000 acres) is currently closed due to unsatisfactory water quality (New York State Department of Environmental Conservation 2010).

Certified Forest Products

Forestry certification programs have been in existence for many years and have obtained commitments to purchase sustainable products from numerous forest owners and companies that purchase wood products. Multiple organizations currently certify forests as sustainably managed and track the chain of custody for these certified products. The primary challenge for certified forest products is consistent demand for and supply of sustainable products.

Information garnered from tracing certified forest products can be applied towards tracing seafood. Primary lessons include the need to get large companies within the supply chain to demand traced and certified products. Additionally, information from tracing certified forest products can illustrate potential problems that seafood tracing will face, as well as potential clientele characteristics.

Certification programs in various business sectors may provide insight for the creation of a successful traceability and certification program in the seafood industry. One example is the certified wood products program, first introduced in the early to mid 1990's (Anderson and Hansen 2004). Like many restaurants' commitment to purchase sustainable seafood, various large wood retail companies have pledged to purchase "forest friendly" wood (e.g. Home Depot, Lowe's, and IKEA) (Irland 2007; Anderson, Hansen, and Wagner 2002). Large producers sell the majority of wood products to industrial buyers, with only a small percentage of products sold directly to consumers. These high volume buyers look for quality, not brand name, while consumers often look for brand name over quality (Irland 2007). Volume buyers are also likely to value environmental attributes less than quality (Damery and Fisette 2001). Like seafood, wood normally goes through many channels before it reaches

the consumer—it is not unusual for the distribution chain to include six or more links (Irland 2007).

Several factors influence the demand for certified wood products. High-end consumers will be likely to purchase higher priced certified wood products, and seasonal or small volume products may have more success with certified wood products due to a smaller chain of custody. Also, regular and predictable purchase schedules are preferable and make suppliers more likely to participate in sustainable product purchasing. Additionally, wood products are easier to certify if they are in close proximity, geographically, to the certifiers. Forests that are closer to certifiers are easier and less costly to monitor, due to decreased travel time and distribution costs (Irland 2007).

Finding sources for certified wood products could be challenging for retailers. Retailers often need many different types of wood, and thus must purchase from several different mills. Retailers also often need large quantities of wood and must purchase from multiple mills to fulfill an order (Irland 2007). Finally, retailers may demand so little wood that its suppliers cannot change purchasing practices to supply the retailer with certified wood products (Bowe and Hubbard 2003). For a forest certifying body to fully certify a wood product, mills must not mix the certified wood with uncertified wood. Most mills cannot purchase and sell only certified products due to inconsistent demand for those products, and therefore must invest extra time and expenses to segregate products (Humphries, Vlosky, and Carter 2001). The seafood industry faces similar segregation challenges; a fishery often only sells one species or type of seafood, but distributors may buy and sell many different types of seafood. Restaurants and suppliers then demand different types of products, further complicating the issue. The seafood chain of custody, similar to a wood product supply chain, is far from linear.

Prominent North American certified wood products certifying bodies are the Canadian Standards Association and the Forest Stewardship Council. Under the Canadian Standards Association's chain of custody standard, tracing is a voluntary step that forest managers and entities along the supply chain may take once a forest has been certified as sustainably managed. Canadian Standards Association uses Programme for the Endorsement of Forest Certification Annex 4, an internationally recognized Chain of Custody Standard, to evaluate forestry products (CSA 2010). Canadian Standards Association uses third party auditors to do the evaluations of forests. A physical marking is made on each wood product or on a bundle of wood products. This marking distinguishes the wood product as having originated from a forest certified by Canadian Standards Association. Wood products can have one of three markings, depending on type of product and level of certification. Marking One is only for solid wood that has a minimum 70% certified wood and the remaining 30% must not come from a controversial source. Marking Two is for composite wood with the same 70%/30% ratio as marking one. Marking Three is for wood products

that are 100% certified and kept separate from non-certified wood products throughout the entire chain of custody (CSA 2010).

The Forest Stewardship Council, like the Marine Stewardship Council, was started by World Wildlife Fund. The Marine Stewardship Council Chain of Custody standards have many of the same requirements as the Forest Stewardship Council Standards. One main difference with the Forest Stewardship Council standards is the scope of the Chain of Custody system. The Forest Stewardship Council deals with a multitude of mixed inputs. These mixed inputs have varying percentages of certified and noncertified timber (FSC 2010). In order to account for this combination, the Forest Stewardship Council requires four categories of products, referred to as product groups. These include: Pure, Mixed, Recycled, and Controlled Wood (FSC 2010). The "Mixed" group allows the consumer to know what percentage of the wood product is Forest Stewardship Council certified and which percentage is not (FSC 2010). For example, "Forest Stewardship Council Mixed 70%" tells the consumer that 70% of wood inputs into the product are Forest Stewardship Council certified. Many seafood products are mixed during processing, and this would be one way to allow the more sustainable fisheries to profit from their practices.

Organic Food Certification

The organic food industry has extensive certification and accreditation measures for its products, and these measures have engendered trust among consumers and allowed product suppliers to profit from responsible practices. Group certification systems have been established to allow smaller-scale producers of organic food to differentiate their products at a manageable cost. Consumers of organic food have demonstrated a willingness to pay higher prices for food that is cultivated in an environmentally sustainable manner.
Seafood could potentially use relevant aspects of the certification measures for organic food to make product verification within the seafood industry more efficient and effective. With a seafood product tracing system that can be reliably verified, seafood suppliers could enjoy economic benefits from the ability to guarantee consumers that designated products are harvested responsibly. Creating an incentive for each member of the seafood product supply chain to undergo some form of certification is a major challenge, and decreasing costs through group or local certification processes, as is done with organics, may be effective.

Organic food certification programs began as local or regional farmer-based groups seeking to share information and certify members. Governments set national standards as the production and trade of organic foods grew and started accrediting certifying bodies to standardize the effort. The process of certifying organic food involves setting standards for food production, production facilities inspections,

verification of operating records, and approving the producer or processor of the product (Lohr 1998). Organic certification also restricts the use of synthetic additives and prevents fraudulent "organic" labeling, thus inspiring consumer confidence and willingness to pay. Data from the EU illustrates that this label confidence does exist, as 20-38% of consumers in the EU buy organic food at least occasionally, and organic food in the EU is priced 10-50% above the price of conventional food products (Lohr 1998).

Although the organic food industry has experienced growth and increased recognition, the system could still improve. Uniform standards for the different categories of organic food would simplify the certifying process for producers and increase market efficiency, but this uniformity does not exist. Different private certifiers set their own standards and labels, which are checked by accreditors to ensure that they meet minimum government requirements (Lohr 1998). Accreditors consist mainly of national and transnational government entities that possess legal authority or broad market recognition. In areas where the trade of organic food takes place on a small scale, private accrediting and certifying entities assume the role of approving organic food rather than government. For both private certifiers and government regulators, production techniques are the main point of emphasis, while farmer-based organic certifiers focus on member participation and ideological principles. Private and farmer-based certifiers operate from the local to international scale along with government standards. In Germany alone, there are fifty autonomous control bodies and eight farmer's associations that certify organic products (Lohr 1998).

The EU has an extensive organic certification system anywhere and regulates all aspects of the organic marketing chain (Barrett et al. 2002). All goods imported to the EU under the organic label must meet EU regulations for production, processing, documentation, inspection, and certification. Once an organic producer is certified, the producer must pass annual inspections to remain certified. One major dilemma for small-scale organic producers is whether to choose an international or local certification body. Local certifiers will have better knowledge of local conditions, will have an easier time communicating with the producer, and can make random inspections more frequently than an international certifier. Using local certifiers keeps money in the local economy and lowers costs for producers. The drawbacks, however, are that local certifiers may lack resources and information initially, and may have difficulty achieving international recognition. One way for small-scale farmers to reduce costs of international certification is by forming a producer group or co-operative and becoming certified as one combined body, while still only paying one fee for certification (Barrett et al. 2002).

While certification is a major and critical component of the organics industry, there is also a tracing element involved in the process. In the US, domestic applicants who wish to have their product certified as organic must first prove that the product was

grown in the US (USDA 2007). To do this, the applicant must provide records that describe the history and location of the product, as well as any alteration it may have undergone. This information must allow the verifier to trace the product back to where it was initially grown (USDA 2007). If a product is being investigated for possible non-compliance with organic standards, US Department of Agriculture inspectors will conduct a "trace-back investigation", in which they determine the geographic origin of the product and its subsequent distribution. This is accomplished by acquiring product handling records and determining from where the product was distributed and in what amounts (USDA A 2009).

Sustainable Seafood Certification and Labeling and Consumer Response

Eco-labeling is a growing industry that is trying to address consumers' desire for more information on the environmental characteristics of the seafood that they purchase. In order to be successful, organizations must build trust with and visibility for consumers, and credibility within the seafood industry. They must also contend with other, potentially competing, factors that influence purchasing decisions.

An effective, verifiable, full chain of custody tracing system could add credibility and trust to an eco-labeling or certification program, increasing acceptance and adoption.

Eco-labeling is used today for thousands of products in over 200 countries (Teisl, Roe, and Hicks 2002). Non-governmental organizations and other private organizations use eco-labels to educate consumers about the environmental effects of the production of labeled products. Businesses use eco-labels to distinguish their product in crowded markets. Both groups aim to change the purchasing behaviors of consumers: non-governmental organizations to reduce environmental harm, and businesses to gain a larger market share and increase profits (Jacquet and Pauly 2008). While studies have shown that eco-labeling has increased awareness, there has been little evidence that consumer behavior has changed dramatically due to the labels (Jacquet and Pauly 2008). Seafood eco-labeling (i.e. labeling seafood and other products as organic or sustainable) is a new development in the labeling and certification sector (Potts and Haward 2007).

One of the biggest challenges that any successful certifying organization must overcome is gaining the trust and visibility of the public and obtaining credibility within the industry (Peacey 2000). Increased stakeholder involvement in the creation of standards and criteria will improve satisfaction among consumers and industry members (Chaffee et al., 2003). Additionally, it is important for the certifiers to use verifiable criteria to avoid discrediting themselves (Thrane, Ziegler, and Sonesson 2009). Consumers should be able to trust certifiers and understand the implications of a label without having to understand everything that went into labeling. This can be complicated, especially when different guides are making seemingly or truly

contradictory recommendations (*Figure 2*) If there are too many labels with different or competing meanings, consumers may disregard the labeled product and return to the non-labeled options, thus undermining all efforts (Potts and Haward 2007).

Labeling programs, such as informational wallet cards that help consumers identify sustainable products, measuring devises that help prevent the purchase of juvenile fish, and cookbooks that aid in the preparation of seafood may increase the demand for sustainable products and create incentives for sustainable fishing (Jaffry et al. 2004). However, despite the prominence and visibility of Monterey Bay Aquarium's Seafood Watch Program, a self-study showed no overall change in the market for targeted species (Quadra Planning Consultants Ltd. and Galiano Institute for Environmental and Social Research 2004). This does not, however, prove that other forms of eco-labeling cannot be effective, but may suggest that the Aquarium's program has room to grow. A stated-preference study in 2004 showed that consumers were more likely to choose seafood products that were labeled as sustainable by a government agency than by a private organization (Jaffry et al. 2004). Studies have also shown a historical response to eco-labeling and educational campaigns in tuna, tilapia, and swordfish markets, although the purchasing decisions may have also been influenced more by health concerns than by sustainability issues (Jacquet and Pauly 2007; Teisl, Roe, and Hicks 2002).

Ultimately, consumers take into account many attributes when buying seafood. "Quality, brand, safety, price, personal experience, and product promotions" will all compete with environmental concerns when consumers are making purchasing decisions (Wessells, Johnston, and Donath 1999). The most effective eco-labeling schemes will target those who are the most influenced by sustainability concerns: consumers who purchase large amounts of seafood, belong to an environmental organization, and have specific awareness of species that are overfished or threatened with extinction (Wessells, Johnston, and Donath 1999).

Consumer and Retailer Attitudes and Preferences

Customers and retailers would like more information about the source of the seafood that they buy and base part of their purchasing decisions on the environmental effects of the seafood they purchase. The majority of retailers also say that verifying the chain of custody and source of their products is difficult.

Tracing could address many of these issues by providing easily available information on both the source and chain of custody of seafood products. Tracing could answer questions that both consumers and retailers have about their seafood and build confidence in the products that they purchase.

While the US Department of Agriculture requires Country of Origin Labeling for many seafood products, recent surveys have shown that both consumers and seafood retailers desire more information on the products that they buy and sell. In 2001, the Seafood Choices Alliance, a program of the Non-governmental organization, SeaWeb, surveyed 1,000 individuals on their seafood buying habits and attitudes. Several years later they surveyed 357 chain restaurants, retailers, and wholesalers who sold fish or shellfish. In 2008, they compiled the responses into a report (Seafood Choices Alliance 2003; Seafood Choices Alliance 2008). The consumer survey found that while over half of respondents had heard significant amounts of information about the health benefits of eating seafood, only a third were significantly aware of the harmful environmental impacts of some types of commercial fishing. According to the study, over half could not say if the seafood they bought was wild caught or farm raised, and 74% were at least somewhat interested in getting more information on the origin of the fish they purchased. Furthermore, Seafood Choices Alliance found that while 71% of consumers said they would be more likely to purchase seafood if it had an "environmentally responsible label," 78% said they felt like they did not have enough information to identify overfished or environmentally harmful fisheries.

The survey of industry members found that 90% of chain restaurants, 88% of retailers, and 75% of wholesalers are at least somewhat interested in getting more information on environmental issues related to seafood. When making purchasing decisions, 62% of the retailers take into account whether the species they purchase is caught in a way that harms the marine environment while 58% consider if the species is overfished. Finally, almost half of surveyed restaurants say verifying the chain of custody and source of the seafood they buy is challenging (Seafood Choices Alliance 2008). Another study demonstrated the uncertainty that surrounds seafood products as 33% of respondents indicated that fresh fish is unsafe (Seafood News 2008).

Economic Incentives for Tracing

Substantial economic benefits may result from seafood tracing. These economic benefits include higher revenues from decreased illegal, unregulated, and unreported fishing, decreased product switching and product adulteration, increased potential for brand recognition, decreased time spent in the event of a product recall, and increased savings due to better efficiency in complying with government regulation.

A successful seafood tracing system should require that companies within the seafood industry provide more information on the supply chain and that the information be more transparent than the status quo. However, without a government mandate, companies may not have enough incentive to participate in tracing unless there is potential to increase their market share, relative to competitors who cannot make

similar claims. Additional seafood tracing information may be provided if companies are convinced that the marginal benefit of providing the additional information is greater than the marginal cost (Wessells 2002). Fortunately, tracing will likely result in an economic benefit to fishers and companies that are using the best management practices, delivering the highest quality product, and acting as the best resource stewards (Wessells 2002).

Tracing can provide pertinent information to regulators and the seafood industry to help identify companies that are not complying with catch limits or fishing regulations. This additional knowledge will help to decrease IUU fishing. Therefore, the companies and fishers that are complying with applicable regulations and quotas will be able to use less effort to catch the same amount of fish due to decreased competition with illegal fishing (NOAA IUU 2009).

Brand recognition is gaining importance in the increasingly competitive seafood industry (Wessells 2002). With increased tracing, a company or geographic area can better keep its brand name associated with the product throughout the supply chain. This may potentially increase profits for the fisheries with the best management practices. The state of Alaska is working to use branding to associate the word "Alaska" with seafood that is sustainable and possesses superior quality and taste. The Alaska Seafood Marketing Institute, a marketing board that promotes Alaskan Seafood, recently conducted a survey that found that adding the word "Alaska" in front of seafood dishes on a menu greatly increased the likelihood that the dish would be ordered by the consumer (Alaska 2010). This study illustrates the success that the state of Alaska believes it has when marketing its seafood products. Therefore, effective tracing of these products that keeps the "Alaska" brand associated with the fish becomes an important component of their marketing programs.

Implementing tracing also allows seafood buyers to increase profits by increasing their ability to document the sources of and distinguish between higher and lower quality products. The ability to better predict seafood quality is valuable due to the inherent difficulty in determining the quality of meat when a fish is in either whole or headed and gutted form (Babcock and Weninger 2004). With increased product tracing, clients may be able to trace quality and conservation parameters for each fishery, and shift purchasing preferences in order to increase resale profits.

A robust tracing system will also enable seafood companies to save time and money complying with current and future government regulations and in the event of a recall. The EU has recently adopted strict documentation requirements on imported seafood in an attempt to decrease IUU fishing (see "US Catch Documents for exports to the EU"). Improved tracing could also be used to save seafood companies large amounts of money if they could prove to regulators that their products did not come from a contaminated source in the event of an industry-wide recall of a specific fish product.

Large-scale tracing of seafood may only occur as the result of government mandates or significant economic incentives. Tracing seafood has the potential to increase trust by clients through greater transparency. Moreover, tracing may also decrease IUU fishing and promote better practices within the seafood industry. Additionally, more robust tracing will decrease the costs associated with regulation compliance and costly recalls.

Summary

This review demonstrates the need, and, in many cases, demand for a seafood tracing system used throughout the industry. It also suggests that a tracing system has the potential to close many gaps in current seafood legislation and non-governmental efforts, in part by adopting measures from other industries, such as wood and organic food products. The literature shows that a tracing system must address a wide scope of problems to be successful, including illegal fishing practices on the high seas, legal yet environmentally degrading fishing and farming methods, and inaccurate labeling of seafood. Finally, a tracing system must satisfy a wide array of needs from local fisheries to an industry that spans international markets.

Case Studies

Introduction

Monterey Bay Aquarium's Seafood Watch program was formed in 1999 to promote the purchase of sustainable seafood and encourage the protection of the ocean ecosystem. Seafood Watch develops and publishes recommendations that consumers can use to help guide them when purchasing seafood. Fish species are designated as "Best Choices" (Green), "Good Alternatives" (Yellow), or "Avoid" (Red), depending on a series of considerations the Aquarium has established. These include: 1) the status of the stock, 2) the management method in place, and 3) catch method. Consumers are encouraged to primarily buy Green-labeled species, while avoiding products that carry the Red designation. As part of their outreach efforts, Seafood Watch has also begun to partner with seafood suppliers to help increase the awareness of, and encourage the market for, sustainable seafood. In 2009, Monterey Bay Aquarium partnered with our group in order to have us evaluate the strengths and weaknesses of several possible tracing scheme options, and to make recommendations on how tracing may be effectively and widely implemented by their industry partners.

Santa Monica Seafood is a seafood distributor that is based in the Los Angeles area, and is the largest seafood distributor in the southwest US. They are a regional operation, with two retail stores and a wholesale division that sells seafood in Southern California, Las Vegas and Phoenix. The company has approximately 1500 customers, and sells its products primarily to high-end restaurants, casinos, hotels and resorts. They currently sell 15 Marine Stewardship Council certified species and one Aquaculture Certification Council certified species. In late 2009, Santa Monica Seafood partnered with the Monterey Bay Aquarium and pledged to buy a majority of their seafood from sustainable sources within the next 5 years. They plan to increase the number of Green or Yellow listed products and are interested in tracing schemes that would help verify the source of the seafood they buy (Kock 2009). By improving the access to sustainable seafood, they hope to match the rising consumer demand for sustainable products.

After discussions with Santa Monica Seafood, we decided to use three case study species as a main focus of our research. Our goal for using case studies was to understand current tracing methods, stakeholder perceptions of various tracing schemes, and potential barriers of implementing a new tracing system. The products we used for these case studies are: farmed salmon, sea scallops, and yellowfin tuna. These products represent a variety of seafood types, countries of origin, catch methods, and management programs. Each of these species presents unique tracing challenges and each has different needs for increased ecological and economic

benefits from tracing. The motivation for tracing each case study species is as follows:

Farmed Salmon- Farmed Finfish
The salmon that Santa Monica Seafood buys from its supplier comes from many different farms, and the sources of individual fish are often hard to determine due to comingling by the supplier. Tracing would allow Santa Monica Seafood to buy salmon from farms that have the most ecologically friendly management practices, and would allow them to avoid farms that have high levels of the fish disease Kudoa, which would prevent the economic loss that is associated with diseased fish.

Scallops- Wild and Farmed Shellfish
The scallops that Santa Monica Seafood buys often come from multiple countries and it is difficult to determine the origin by sight. Tracing would allow SMS to identify scallops that came from countries with stricter and more sustainable management regulations, such as the US and Canada, and also avoid the smaller products from Russia that are often adulterated and substituted for larger species that carry a price premium.

Tuna- Wild Finfish
Santa Monica Seafood sources Tuna from a variety of fishing vessels using a range of catch and processing methods. The catch method and locations are often very important when determining where the product falls on Monterey Bay Aquarium's Seafood Watch list, while the processing method can determine the resale value of the fish. Tracing would allow SMS to buy fish caught by vessels that are known to provide both sustainable and high-value products.

Farmed Salmon

Seafood Watch Score
Farmed: "Avoid"
Farmed in Tank Systems: "Best Choice"

Species and fisheries background

Our first case study is farmed salmon, also referred to as "farmed North Atlantic salmon," or simply "Atlantic salmon." Farmed salmon has rapidly grown to fill a large portion of the global salmon market, accounting for just 1% of the market in 1980 and 60% of the market in 2003 (Eagle, Naylor, and Smith 2003). Today, salmon farms have more than doubled the total salmon market and have led to price decline for all salmon products (Eagle, Naylor, and Smith 2003). Salmon aquaculture is now over a $450 million industry (Stokstad 2007). Farmed salmon is raised internationally, with farms in Norway, Chile, The British Isles, Canada, Australia, and the US (Fleming et al. 2000). In addition to changing the market value of wild

salmon, farms impact wild populations, leading to decreased fish stocks. Additionally, farmed salmon poses many health risks (see Aquaculture with a focus on one of our case studies: farmed salmon).

Company Background

Calkins & Burke

Santa Monica Seafood sources their farmed salmon from Calkins & Burke, a Canadian food broker founded in 1914 (Calkins and Burke 2010). Calkins & Burke sells farmed Atlantic salmon from many international sources to over 100 suppliers. They sell fresh, frozen, and canned seafood products both domestically and internationally. In our communication with Calkins & Burke, we learned about how they trace farmed salmon, their motivation for tracing, and limitations to their current tracing method.

Current Tracing

In our communications with Calkins & Burke (2010) we discovered that, as with our other case studies, the company currently has an internal chain of custody system in place for farmed salmon for food safety reasons. A tracing system is required in order to trace their product back to its source in the event of a recall. Included in the supply chain are any inputs, such as feed. This system is well developed, and Calkins & Burke is able to trace each shipment of salmon they receive and sell to the pen that it was grown in. If needed, the production code or lot number should be able to trace the fish back to the original farm. Additionally, Calkins & Burke is Marine Stewardship Council (MSC) certified. Though farmed salmon is not certified by the MSC (the MSC does not certify any aquaculture products), the system in place at Calkins & Burke is in accordance with MSC's Chain-of-Custody standard.

Calkins & Burke does not have a large threat of external audits for tracing their product. They use an internal system to trace their salmon, with the only external regulation coming from the potential of an audit by the Canadian Food Inspection Agency. The Canadian Food Inspection Agency is responsible for the food safety of all federally registered facilities and can audit the facility annually. In addition, the facility is required to do a mock traceability program bi-annually, which can also be included in the audit to ensure effectiveness of the facility's traceability.

Maintaining all of the information on the supply chain for farmed salmon is difficult because of the volume of fish moved, and, in regards to fresh products, the speed at which it is moved. Suppliers claim that maintaining all of the tracing information along the supply chain would slow the process down. Instead, each link in the chain relies on the next person to keep the information they provided, which is a "one-up, one-down" method of tracing. Another claim is that it is necessary to limit paperwork or the process will not get done properly. Thus, in the current system it is possible to contact each party and obtain the information from the product handler before them,

but the end consumer cannot access all of the information in a comprehensive report at the end of the supply chain.

Challenges

Salmon farms are associated with many environmental and health issues (see "Aquaculture with a focus on one of our case studies: farmed salmon"), some of which a tracing system could address. One of these issues, feed, is a pressing social issue with farmed products, because the biomass necessary to feed farm fish is often greater than the biomass produced, thus leading in a net loss in biomass (Monterey Bay Aquarium Salmon 2010). Therefore, understanding the characteristics of the feed a farm uses, and choosing feed from responsible sources is imperative to reducing the negative impacts from salmon farms. This understanding may be difficult, if not impossible, to obtain without a tracing system that starts at the origin of the feed source. Some of the farms Calkins & Burke purchase salmon from source their fishmeal from fisheries that are certified by the MSC, Friends of the Sea, or other certifying bodies, yet Calkins & Burke notes that tracing the feed is a challenge. They know where the feed in each lot comes from directly before they purchase it, but do not know the supply chain before that point of contact. When considering tracing, this is a limitation in understanding the entire supply chain.

In our communications with Calkins & Burke they stated that farmed salmon is generally seen as an affordable option for healthy protein, and the consumers purchasing farmed salmon are not likely to demand traceability because they are price conscious and not as concerned with sustainability issues as consumers of wild salmon. Without consumer demand for traceability, there may be little economic benefit for companies to trace. Many farms are taking steps to source from sustainable aquafeed providers and to clean up their farms, but this is not always marketed to the public.

The Monterey Bay Aquarium has listed farmed salmon raised in ocean net pen farms as a species to avoid, due to the environmental impacts on the ecosystem of wild salmon populations (Monterey Bay Aquarium Salmon 2010). Additionally, the Aquarium notes the associated feed ratios of three-to-one, and the health impacts as described by the Environmental Defense Fund. The exceptions to the "Avoid" list are salmon farmed in tank systems. The use of tank systems reduces the risks associated with pollution and disease, as well as escapees (Monterey Bay Aquarium Salmon 2010). With a tracing system in place that identifies the source of salmon feed, some more traditionally farmed salmon industries could move off the "Avoid" list.

Motivation for Tracing

Farmed salmon was chosen as a case study for this project because of the potential economic benefits traceability can lend to environmentally friendly farming operations, such as those that use tank systems. Consumers have been warned of the effects of farmed salmon, and in response many farms are trying to market their

product as something other than farmed, hence the coined name "Atlantic salmon." This is considered consumer fraud, and leads to further challenges for both wild caught products and salmon coming from responsible farming practices. Farmed salmon raised in tank systems only recently became a "Best Choice" species by the Seafood Watch (Monterey Bay Aquarium Salmon 2010), and it is economically important for these farms to benefit from this recognition. These best-practice farms will not receive an economic benefit from their efforts unless they are able to differentiate themselves from their competitors. One-way to do this is through the implementation of a tracing procedure that gives customers confidence that the product comes from an environmentally responsible source. If sustainable farms are able to differentiate themselves with the help of tracing, people may be more likely to purchase these products, and farms may be able to profit from their responsible practices.

Important Considerations for Recommendations

Farmed salmon is a high volume fishery and needs to maintain high product speed throughout the supply chain. Confidentiality of supplier and client information is also a concern with farmed products. The threat of a recall is also present with farmed salmon, thus a system that stores the supply chain history in one location would likely increase efficiency. Finally, farmed salmon is relatively inexpensive in comparison to other types of fish, and certain tracing systems may be cost prohibitive because there is not sufficient demand.

Wild Scallops

Seafood Watch Score
Bay Scallops: "Best Choice"
Sea Scallops: "Good Alternative"

Species and Fisheries Background

For our second case study, we chose sea scallops harvested in the US. Two types of scallops are commercially available for human consumption: bay scallops and sea scallops. Bay scallops are farmed, come from many locations (not restricted to a true bay), and may be farmed on-bottom or off-bottom (McNevin 2006). The Monterey Bay Aquarium classifies off-bottom harvested scallops as a "best choice" because the scallops grow off the sea floor, must be harvested by hand, and thus the fishing fleet has little impact on the benthic environment (McNevin 2006; Monterey Bay Aquarium Scallops 2010). Sea scallops are wild caught from their natural environment, which consists of shallow, coastal, ocean waters. The Monterey Bay Aquarium calls US Sea Scallops a "good alternative" (Monterey Bay Aquarium Scallops 2010). Fishing fleets dredge sea scallops, a practice that catches a variety of species of bycatch and damages the habitat (Hendrickson 1984; McNevin 2006; Monterey Bay Aquarium Scallops 2010). Furthermore, there is only a "moderately

effective" fishery management plan in place (McNevin 2006). These factors remove sea scallops from Seafood Watch's "best choice" list. Scallops are filter feeders: thus scallops from polluted sources may contain harmful contaminants for consumers, but this also means that farmed scallops do not require any added nutrients or feed. Scallop stocks are "healthy and abundant" and the fishery has not had a negative impact on wild populations (Halpin 2008; McNevin 2006; Monterey Bay Aquarium Scallops 2010).

Company Background

Northern Wind

Santa Monica Seafood partners with and buys scallops from Northern Wind, a seafood company based out of New Bedford, Massachusetts. This company sources seafood from a fishing fleet compiled of independently owned boats, offloads fresh products from the boats, processes a variety of products, and distributes fresh and frozen products around the world. Northern Wind offers bay *(argopecten irradians)*, sea *(placopecten megallanicus)*, or callico *(argupecten gihhus)* scallops, either as fresh or frozen. Northern Wind sources its seafood from a fleet of 150 independently owned boats that fish over George's Bank, in the Northern Atlantic, for 7-10 days at a time, divided over the government-set limit of days at sea (Morrison 2009). While at sea, all these boats use federally regulated drag nets to dredge the scallops. Northern Wind has a verbal agreement with some of the boats they buy from that the boats will only sell to Northern Wind and that the company will pay the market price for scallops. Northern Wind buys the scallops at auction from the remaining boats that they use in the fleet (Morrison 2009).

Current Tracing

Northern Wind has an internal tracing system. The company monitors its fishing fleet: they know where each boat fishes, how much product each boat brings in, and each boat's time at sea (Morrison 2009). Northern Wind also stays in compliance with Food and Drug Administration standards, including processing and handling of shellfish, and both federal and state regulations for fresh food (Northern Wind, Inc 2002). Northern Wind currently undergoes a number of audits and inspections throughout the year to meet requirements for selling shellfish (Northern Wind, Inc 2002). In the event of a health issue or a recall, Northern Wind can trace the product in question back to the boat from which it was caught (Morrison 2009). Similarly to our other case studies, this tracing information is not kept in one distinct place that can be easily accessed. Clients of Northern Wind do not have access to this information, thus consumers also do not have access.

During live auctions at the docks, Northern Wind assigns a lot number to each shipment bought, which can be quantities of 5,000-10,000 pounds of scallops per

shipment (Morrison 2009). This lot number remains with the scallops until Northern Wind sells them either to a distributor or a wholesaler (Morrison 2009). When the scallops leave Northern Wind, information regarding quality, sizing, and pricing accompanies the scallops (Northern Wind, Inc 2002). Fresh shipments include the date the product was packed. In addition to such catch-specific information, scallops from Northern Wind are labeled as North Atlantic scallops (Morrison 2009).

Challenges

One of the biggest challenges associated with scallops is the wide variety of species that face consumers labeled as "scallops." The vast majority of scallops consumed in the US are wild caught scallops from the US. Only approximately 4% of US scallop consumption is farmed scallops, and the majority of these come from Japan or China, countries that often have less responsible environmental fishing practices (McNevin 2006). Among US sea scallop products, the colder waters of the northern Atlantic produce higher quality scallops than scallops grown in warmer, mid-Atlantic waters, and Northern Wind makes it a point to label their products as "North Atlantic Scallops" (Morrison 2009). The quality of a scallop is measured in size and "juiciness": the "juicier" the scallop, the more money it brings in (Kock 2009). Therefore, scallops are generally sold by wet weight. To increase their competitiveness in the market, some industries will adulterate their scallops by soaking them in or injecting them with excess water (Hedlund 2007). If products are adulterated beyond a regulated point it is illegal, but this practice is often difficult to identify and prevent (Kurtzweil 1997).

Another challenge for tracing scallops is the amount that is sold as processed products (Kock 2009). It is more difficult to track commingled, altered or highly processed products, as they may not be readily identifiable and may not need to be segregated, labeled or monitored under government regulations (USDA D 2009). Buyers of this type of product may not be looking for high quality or specific characteristics of scallops and may not pay attention to the source or type of scallop. If these factors are true, there may be little demand for traced scallops.

Finally, even slightly processed scallops are difficult to identify. The different varieties of scallops look similar once out of their shells (Kock 2009). The similarities could make verifying traced scallop products difficult without incorporating new and potentially expensive technology or inhibiting the speed of product movement.

Motivation for Tracing

Introducing a tracing scheme into the scallop industry would allow buyers along the supply chain and consumers to differentiate between scallop fishery practices. Distinguishing between dredged, on-bottom farmed scallops and hand harvested, off-bottom farmed scallops would allow buyers and consumers to make a choice with sustainability in mind. With a means of differentiation in place, Monterey Bay

Aquarium could easily qualify on-bottom scallops as a product to "avoid" while promoting the other more responsibly harvested products.

Tracing may also help identify, and potentially reduce, product fraud within the scallop fishery. Scallops from Canada and the US are more expensive than those from other countries and, as with many seafood products, product switching or substitution is always a possibility (Morrison 2009). Tracing would help expose this practice. As with many industries, some company names are more trusted and well known than others (Kock 2009). In the scallop industry, the trusted companies may be ones that do not adulterate their products or practice product switching. Tracing would allow consumers to recognize these products, distinguishing them from less reliable products, and choose to purchase the most sustainable product.

Important Considerations for Recommendations

Like other forms of shellfish sold in the United States, the scallop industry must meet strict government regulations with regard to product sourcing and handling procedures. These regulations ensure that each container of scallops has an attached tag containing product and source information, allowing for reliable tracing back to the harvest location of the scallops in the event of a recall. A system that maintains this information in a centralized location would be helpful to provide data on products to members along the supply chain, certifiers, and government auditors who need certain information. This may include product handling and transformation, such as continuous, streamlined monitoring of product temperature as it makes its way through the supply chain. A system should discourage the practice of scallop adulteration, and a system that has better detection of fraud would be preferable. Finally, sellers should have the ability to provide consumers with more detailed information, giving them greater confidence that the product they're purchasing is uncontaminated and harvested in an environmentally responsible manner.

Yellowfin Tuna

Seafood Watch Score
Canned Worldwide: "Avoid"
US Atlantic, Troll, Pole-and-line: "Best Choice"
US Atlantic, longline: "Good Alternative"
Worldwide, Except US Atlantic, troll, Pole-and-Line: "Good Alternative"
Worldwide, Except US Atlantic, Longline, Purse Seine: "Avoid"

Species and Fisheries Background

For our third case study, we chose yellowfin tuna. Yellowfin tuna is referred to by many names, such as Ahi, Canned Light Tuna, Maguro, and Toro (Monterey Bay Aquarium Yellowfin Tuna 2010). It is a highly migratory pelagic fish and is caught in equatorial waters of the Pacific, Atlantic, and Indian Oceans (Garrett and Brown

2009). Yellowfin tuna accounts for 25% of the world's total tuna catch, and ranks second among all tuna species in terms of total volume caught. The majority of yellowfin catch occurs in the western Indian Ocean, which has a seasonal fishery, and the west-central Pacific Ocean, where fishing takes place year-round (Marsh 2008). The predominant method of catch in yellowfin fisheries is purse seine, although long-line fishing also accounts for a substantial percentage (Garrett and Brown 2009). These catch methods are a significant environmental concern of the yellowfin fishery, as both purse-seine and long-line fishing can generate significant bycatch of untargeted marine organisms (Marsh 2008). The ability to uncover the source of a tuna product is essential in promoting more responsible fishing practices, such as handline and pole-and-line (Monterey Bay Aquarium Yellowfin Tuna 2010).

Company Information

This project profiles two companies that distribute yellowfin tuna—Naturally New Zealand, and Central Pacific Tuna.

Naturally New Zealand

Naturally New Zealand is a seafood supply company headquartered in California and imports seafood from the South Pacific Ocean. Its Fijian tuna supplier is Solander Pacific Limited, which operates a fleet of longline vessels out of Suva (Naturally New Zealand 2010). Naturally New Zealand sells the yellowfin tuna that it receives in a headed and gutted form to various wholesalers, including Santa Monica Seafood, who then process and sell the tuna to restaurants, retailers and consumers.

Central Pacific Tuna

Central Pacific Tuna acts as a distributor and broker that specializes in importing, exporting, and distributing high quality tuna to meet the global demand for sashimi grade tuna products. Currently it services North America, Japan, and Europe, and has a wide range of business relationships extending across the globe, which enables consistent sourcing of tuna. Central Pacific Tuna's current business model covers product-transfer logistics from the harvesting vessel to a wholesaler or processor, such as Santa Monica Seafood. Central Pacific Tuna keeps product handling at a minimum at its facilities; all processing occurs at facilities overseas, and Central Pacific Tuna distributes the product as is to its clients (Arnett 2010).

Current Tracing Techniques

Naturally New Zealand

Naturally New Zealand receives shipments of tuna from Solander Pacific. Each shipment from Solander Pacific is tracked with an air waybill number, which

identifies the current shipping status and location of each box of yellowfin tuna that Naturally New Zealand is ordering. Solander also provides a daily catch report to Naturally New Zealand that shows the position of each of Solander's fishing vessels, the date of catch, the area of the catch, and the different species each vessel catches. Additionally all Solander vessels are on the Forum Fisheries Agency (FFA) register of good standing. This requires that they be continuously monitored from Honiara by the FFA under their Vessel Monitoring System (VMS). Solander also maintains its own VMS. The company VMS information is available to Naturally New Zealand on request According to Naturally New Zealand; this type of open relationship is rare in the seafood industry and gives Naturally New Zealand the competitive advantage of being able to guarantee sustainable and quality seafood to their customers. Naturally New Zealand can assure against product deception, because the tuna is received from Solander in a headed and gutted form, which enables easy visual species identification. Naturally New Zealand believes that its close and transparent relationship with Solander enables Naturally New Zealand to be confident that the imported tuna is also caught legally.

Additionally, Naturally New Zealand receives copies of the licenses for each Solander vessel, thus ensuring that all of the fishing vessels have complied with the strict Fijian regulations that are used to safeguard against illegal catches (Fig. 3). Since all of the vessels supplying Solander are Fiji flagged and licensed, Naturally New Zealand can be confident that all the tuna that it imports is caught by vessels adhering with management options mandated by Western Central Pacific Fisheries Commission and the Ministry of Fisheries & Forests in Fiji.

Naturally New Zealand does not process or repackage the tuna it receives. It ships out the same boxes of tuna in the same packaging that it receives from Solander Pacific to its wholesale customers. Each wholesale customer is given a carton number, which identifies the species ordered. The wholesalers also receive Hazard Analysis Critical Control Plan (HACCP) and Country of Origin Labeling documents from Naturally New Zealand (Merry 2009).

Central Pacific Tuna

Importers from which Central Pacific Tuna receives tuna are required to provide a certificate stating the product's country of origin, and all suppliers are required by law to have a registry with the US Food and Drug Administration. Central Pacific Tuna uses its own internal systems to track the boat, captain, and ports that are used along the product's supply chain, which enables the company to provide detailed trend data and limit the amount of liability that may occur due to lower than expected quality of product. The system also allows Central Pacific Tuna to identify by whom the tuna was caught even if the product was harvested in a different country from the port where Central Pacific Tuna purchases it. Central Pacific Tuna works closely with the fishing vessels it receives product from, which enables them to ensure that they buy

tuna which is only caught using specific catch methods, namely longline fishing. This preference for longline fishing exists because purse-seine fleet and handline fisheries are not as reliable in providing the product grade that Central Pacific Tuna requires to meet the quality and volume demands of its customers. One challenge for the fishery is finding an environmental and efficient catch method. 98% of the tuna sold by Central Pacific Tuna in the past fiscal year was harvested by longline vessels, which have a less detrimental impact on the marine environment than purse-seine fleets (Arnett 2010). The best quality tuna is harvested on longlines; however Monterey Bay Aquarium rates only handline and pole-and-line as the best for conservation (Monterey Bay Aquarium Yellowfin Tuna 2010). Central Pacific Tuna sees little opportunity for acquiring more product information than it already receives from its suppliers, but is considering purchasing its own vessels so that it can control all information from the tuna supply stage (Arnett 2010).

Challenges

Naturally New Zealand

The most immediate limitation of instituting a more transparent tracing scheme for Naturally New Zealand is that the company already feels that their current tracing practices are sufficient and thus would not voluntarily choose to be subject to more regulation or increased record keeping and reporting. From an economic standpoint, Naturally New Zealand does not believe that there would be an economic gain or competitive advantage from instituting 3rd party chain of custody verification and tracing because wholesale prices for yellowfin tuna have remained relatively static over the last fifteen years. Additionally, fishermen would view any added cost as burdensome and would likely resist because of the potential for decreased profits (Merry 2009).

Central Pacific Tuna

Central Pacific Tuna's priorities when deciding whether to purchase from a supplier include the following: low-cost fish, good payment terms, that the product is delivered on time and in good quality, and that the product is in HACCP compliance. The company's activities are based in providing sashimi grade tuna to wholesalers in the American and Japanese markets, and their customers are less likely to be concerned about environmentally responsible practices when tuna availability is low, which is often the case for this type of high end quality tuna. Central Pacific Tuna purchases long-line caught fish almost exclusively because that catch method produces the highest quality tuna, and since market conditions provide a higher price for higher grade fish, the economic advantage lies with the company's current business model (Arnett 2010). However, Monterey Bay Aquarium lists long-line fishing practices as Red or Yellow because of the high volume of incidental bycatch associated (Marsh 2008). The main concern of Central Pacific Tuna is to manage its

supply chain in order to limit liability, control product movement, and provide the end user with the freshest product possible. In regards to the prospect of more stringent tracing requirements, Central Pacific Tuna stresses the need for enforcement and implementation measures that businesses and consumers can trust. Companies (Central Pacific Tuna included) will not cooperate with new regulations if they do not feel they will be protected when disclosing internal information to comply with a tracing or verification scheme (Arnett 2010).

From Central Pacific Tuna's perspective, the challenges of enhanced and reliable product tracing in the yellowfin tuna fishery are substantial. The commonly used purse-seine catch method, in which many different species are caught, makes labeling fish very difficult, and instances arise where purse-seine caught tuna has entered Central Pacific Tuna's supply chain without the company's knowledge. For both companies, the migratory nature of tuna can make identifying a product's country of origin very difficult, as there is a tendency for boats to fish outside of their home country's waters. Stricter product tracing regulations should be compatible with the ability and concerns of the fishermen catching tuna, as language and education barriers present major hurdles to the successful enactment of these policies. Enforcement of fishing and supply-chain regulations is enormously difficult, and finding a certification or regulating body that can be universally trusted and accepted is also a necessity if uniform tracing standards are to be established (Arnett 2010).

Motivation for Tracing

Tracing yellowfin tuna is important in terms of both conservation and increased economic potential for the seafood industry. With tracing capabilities for yellowfin tuna, Santa Monica Seafood and other distributers would potentially have the opportunity to buy legally caught fish from fishers that use industry approved catch methods. This selectivity would help them to ensure a high quality product, free from internal bruising, which may allow them to charge a price premium.

Yellowfin tuna is a highly migratory species with many shortcomings in terms of data. Research on tuna stocks in the eastern Pacific Ocean lacks fish size and unit of effort information from the Indonesian and Philippine fisheries (Arnett 2010). There is also incomplete data in the Indian Ocean, highlighted by poor knowledge of catches, efforts, and size-frequency before 1980 (Arnett 2010). IUU fishing only adds to the lack of reliable data that is available, and even the statistics, which are provided, may not come from neutral and reliable sources (Marsh 2008). Without reliable information on the status of tuna stocks and their migration patterns, effective fishery management, policy making, and enforcement are challenging.

Important Considerations for Recommendations

Yellowfin tuna's traceability challenges are consistent with other high value fisheries: they need to assure that the product is high quality and that it was not obtained through IUU. Due to the current lack of transparency associated with the yellowfin

tuna fishery, a tracing method which allows the entire supply chain to be accessible in one location would be beneficial to alleviating concerns with IUU. Additionally, verification of the accuracy of information provided is important.

Lessons Learned From the Three Case Studies

The three case studies presented numerous opportunities for, and barriers to implementing full chain of custody tracing:

Farmed Salmon
In regards to farmed salmon, tracing would improve information transfer in a variety of ways. Tracing would enable members of the supply chain to have information on the specific farm where the salmon was raised. This information may be helpful for buyers who wish to purchase farmed salmon that are raised in more ecologically benign ways, which limit ecosystem destruction and interaction with wild species, use feed from sustainable sources, use a low food to fish ratio, and limit the release of disease, hormones, antibiotics and vitamins into the environment. Tracing the source of aquafeed used for farmed salmon would be especially important since it is difficult to visually identify the inputs into most aquafeed. Salmon is often comingled from various farms when sold, without complete supply chain tracing it is difficult to determine the origin. Finally, the common name for farmed salmon is 'Atlantic' salmon, which gives false indication of the origin. Farmed salmon can currently be sourced back to the pen for recall reasons, so tracing would need to consolidate available information. Resistance to tracing farmed salmon lies in the huge volume of product shipped and the concern that information entry will be done incorrectly if documentation is excessive. Finally, farmed salmon is low cost and a good source of protein so many consumers are primarily interested in these characteristics.

Sea Scallops
Although scallops are already highly regulated, additional benefits would result from full chain of custody tracing. Product adulteration and product switching are often problems surrounding scallops. This product deception is possible because it is difficult to visually identify the type of scallop outside of the shell. Complete tracing would allow buyers to ensure they are purchasing from the country and source that they desire both for quality reasons and to avoid adulterated products. A transparent tracing system would also allow product differentiation in terms of farmed products or catch method, whether dredged or hand picked. We also learned that each batch of scallops could be traced back to the boat, thus the information necessary for comprehensive tracing already exists and only would need to be consolidated. Since scallops are highly regulated, a comprehensive tracing system may help with the completion of documentation. Fresh scallops are a luxury good and can command a price premium, thus a slight price increase due to increased tracing costs may not be a large problem. However, similar to farmed salmon, frozen scallops are often bought

in bulk and the consumer is primarily concerned with price and quality more so than environmental concerns. Another difficulty with scallops is that they are often highly processed making it difficult to trace the products.

Yellowfin Tuna

Tracing yellowfin tuna is arguably the most contentious of the three case studies that we examined. Some benefits of tracing that we have noted are that with a comprehensive tracing system in place there may be a decrease in IUU catches. However, yellowfin is a highly demanded product throughout the world, and tracing will only is effective at decreasing IUU products in highly regulated ports and countries. Tracing would also enable yellowfin tuna buyers to ensure which type of catch method is used. This information would be helpful in order to ensure an environmentally sustainable method was used and to ensure that the method used will yield a high quality product, thus avoiding tuna caught with purse-seine fleets. All of the tuna companies that we spoke with had strong relationships with suppliers; this close relationship enables trust in the product. The companies also stated that they have access to information including the fishing locations of the boats, the captain, and the port at which the tuna is landed. High value yellowfin tuna is usually sold in a whole or headed and gutted form, enabling ease of visual identification and an uncomplicated transfer. However, some tuna is used for canning and in this case price is often the most important characteristic. One difficulty is that importers must rely on the regulations of the countries in which the tuna is caught to ensure legal and sustainable management and catch. Since tuna is caught in many different countries, language and education barriers can also present a problem for establishing an accurate tracing system. Another major concern is about the security of proprietary information, which is extremely important within the tuna industry. Any chance of releasing information would yield immediate aversion to tracing. A final challenge is that tuna prices have not increased substantially over the last 15 years, thus any increased cost to the catching sector would likely be contested.

Traceability Schemes

There are many ways to trace a seafood product through the supply chain from its point of catch to the end user. We researched a variety of tracing schemes to determine what parameters are the most important to consider in order to achieve the goals of Monterey Bay Aquarium and their partners. When deciding on a tracing system, we want to ensure that the system will:

- Cover an entire chain of custody "from sea to table", providing necessary supply chain information as well as origin and catch method specific to the individual fish (e.g. a yellowfin tuna) or batch (e.g. a bag of scallops);
- Have credibility among the industry and consumers alike, through a balance between increased transparency and protection of the proprietary information;
- Be enforceable and verifiable through independent party monitoring of provided supply chain information to protect against fraud and instill confidence in the system.

Based on these criteria, we narrowed our viable choices of tracing systems down to: 1) third party verification, 2) online reporting, and 3) product tagging. We explained how the current system works, and provided examples of companies that offer each method of tracing. We also explored the strengths and weaknesses of each scheme, and expanded on the potential for how best to use the system to trace a full chain of custody.

Third Party Verification

Chain of custody verification is one way to ensure that a successful tracing system is in place. In the seafood industry, this system currently relies on independent certifiers with set chain of custody standards. Other industries in which chain of custody systems exist include organics, forestry, and shellfish. In the seafood industry, many companies currently have chain of custody systems in order to trace products back to their original source in the event of a recall (Walsh 2009). Each company may have a different approach to collecting information along their supply chain. Most companies simply trace "one-up, one-down" where each company along the supply chain knows from whom they bought the product and the company to which they sold it. Many companies that already trace their products do so internally, and do not have a third party verifying the system. When implemented throughout the entire chain of custody, third party verification allows for comprehensive knowledge of the supply chain, however, may not provide the end user with the entirety of this information on product movement. This lack of compiled supply chain information allows for gaps in

knowledge of product movement, and can lead to loss of initial data made available, such as catch method.

The Marine Stewardship Council

The MSC is an eco-labeling and sustainable seafood certification program. MSC has two certification programs: fishery certification and chain of custody certification. Both certification schemes use standards that are based on best available science and follow guidelines set by the FAO for the eco-labeling of fish and fishery products from marine captured fisheries (Nistad 2010). In order to receive a fishery certification, the fishery must go through an assessment to prove compliance with the MSC environmental standard for sustainable fishing (MSC 2009). In order to receive chain of custody certification, all members of the supply chain must comply with the MSC chain of custody standard (MSC 2009). Fishery certification can be obtained without the chain of custody certification, whereas the chain of custody cannot be attained without a corresponding certified fishery (Nistad 2010).

In our communications with MSC we learned about the certifying programs (Nistad 2010). The MSC does not directly conduct fisheries assessments and chains of custody audits to check for compliance. Instead, the MSC establishes the standards and accredits certifying bodies to perform the audits. After the initial audit, the certifying bodies may perform unannounced checks on Chain of Custody certified companies. Certifying bodies report information on each fishery into a database in order for MSC to easily map supply chains and access information on all certified products. Once a fishery and the supply chain are granted MSC certification, they must go through annual audits and complete re-assessments every five years. Chain of Custody certification provides assurance that MSC certified fish is kept separate from non-MSC-certified fish

One of the benefits of using the MSC chain of custody method is that it allows for rapid recall because all companies along the supply chain are certified as part of one congruent system. According to the MSC, additional advantages of using their system include: assurance that a fish labeled as MSC certified comes from a sustainable fishery, efficient product recalls, certified fisheries will recognize and avoid any IUU, and independent audits promote the idea of sustainability and inspire trust through transparency.

This project recognizes the lack of continuous surveillance as one limitation to the chain of custody process. Auditors do “1-spot checks of systems and records,” but do not continuously check in on the supply chain. An annual audit provides certifying bodies with the opportunity to catch non-compliance, but without continuous surveillance it is possible for the fisheries to be out of compliance at times. The MSC is implementing projects that would allow them to have a more continuous monitoring system. One such program is called Traceability and Assurance in the

Supply Chain. This program requires "tracebacks"—an exercise that traces MSC certified products back to their original fishery by using transaction history of the product. Additionally, MSC emphasizes that they use the chain of custody standards to evaluate the traceability systems, and not to attempt batch tracking. Companies that provide batch tracking, such as Trace Register and Trace Tracker, may provide an added level of assurance to the traceability of products along the supply chain.

Friend of the Sea

Friend of the Sea is a non-profit organization that uses third party auditors to certify fisheries as sustainable (Friend of the Sea 2010). Unlike MSC, friend of the Sea has a certification program for wild-caught and farmed fish, but does not have a chain of custody certification (Magera and Beaton 2009; Greenpeace International 2010). While chain of custody certification is not a stand-alone program under Friend of the Sea, the company takes it into consideration as part of their certification scheme (Greenpeace International 2010). The non-governmental organization follows FAO Guidelines for the Eco-labeling of fisheries products and claims to be the international leader in sustainability certification (Friend of the Sea 2010). However, some organizations, like Greenpeace and World Wildlife Fund, are skeptical of Friend of the Sea's certification program (Magera and Beaton 2009). Conservationists base their skepticism on the program's weak environmental impact indicators, standards development, and lack of transparency and professionalism, among others (Magera and Beaton 2009; Greenpeace International 2010).

Friend of the Sea uses certifying bodies with auditors that are compliant with accredited, certifying, and auditing standards set by the International Standards Organization, as described in Friend of the Sea's code 0004 (Friend of the Sea 2010). Friend of the Sea's code 0003 determines that during audits, Friend of the Sea observers may accompany the certifying body to the site of the audit to ensure the auditors are using the requisite Friend of the Sea standards (Friend of the Sea 2010). After Friend of the Sea grants a fishery certification, they employ on-site, local monitors to perform periodic, un-announced spot-checks at unloading sites, in the warehouse, or during processing (Friend of the Sea 2010).

Friend of the Sea established criteria for the certification of wild-caught fisheries, farmed fisheries, and fish-oil and other products (Friend of the Sea 2010). In all three fields, Friend of the Sea requires a form of chain of custody monitoring and traceability (Friend of the Sea 2010). Auditors look for a management system in place that must, at a minimum, include three aspects of traceability: 1) maintaining one-up, one-down Friend of the Sea identity as the fishery moves the product along the chain of custody, 2) keeping Friend of the Sea certified products separate from non-certified products, and 3) maintaining records along every step of the chain of custody (Friend of the Sea 2010). The auditor will also check documentation for all steps along the chain of custody up to the point the product is sold to the customer. Documents and

records include Delivery and Offloading fish tickets that connect the product to the fisherman and vessel, Production and Storage documents connecting the product to the fish ticket, cold storage shipping and receiving, customer shipping, and sales receipts. All steps must be connected and identifiable at the final point of sale (Friend of the Sea 2010).

National Shellfish Sanitation Program

The National Shellfish Sanitation Program (NSSP) establishes and enforces sanitation requirements for the growth, harvest, transportation, processing, and shipment of shellfish products (US Food and Drug Administration 2010). These requirements are carried out by federal, state, and local governments, as well as the shellfish industry itself. The duty of inspecting the different stages of the shellfish supply chain for conformance with the established standards falls on state health officials, although adoption of the recommended requirements of the NSSP by state regulatory agencies is entirely voluntary. The inspections are carried out under nationally standardized procedures, and are classified as "systematic surveys of the machinery and efficiency of sanitary control" used by interstate shellfish dealers (US Food and Drug Administration 2010). Even if a shellfish dealer is granted certification after a state inspection, that certification only lasts one year, after which the dealer must be recertified. State officials are also required to make unannounced audits of the facilities of certified dealers, and the frequency of these audits can range from monthly to semiannually, depending on the type of operations carried out by the dealer. If a dealer is deemed in non-compliance, the state can either correct the infraction or suspend or revoke the dealer's certification. Monetary fines and seizure of product are also implemented in certain cases (US Food and Drug Administration 2010).

The National Shellfish Sanitation Program is a strong example of tracing a seafood product, but in its current state, it is not applicable to tracing for sustainability purposes. The program exemplifies that governments can regulate and mandate a tracing system and that information can be successfully transferred from one end of a supply chain to the other. However, the NSSP does not provide detailed information on catch methods, feed in aquaculture production, and other details pertinent to sustainable fishing. Furthermore, the program only applies to shellfish industries, and would need modifications to be applicable to finfish.

Online Reporting

Web based tracing systems provide an electronic system in which information can be reported for each step of the supply chain and stored in one central location. These systems keep extensive records on both internal and external tracing for a supply chain, and can incorporate information from numerous companies. The information

along the supply chain may be controlled in such a way that users only have access to certain information, relieving concerns about forfeiting control of proprietary information. Depending on the level of transparency, consumers may have the ability to follow specific products throughout the supply chain. Web based tracing systems have numerous benefits—the ability to access information for the entire supply chain in one location provides increased efficiency during recalls, increased regulation compliance, and increased trust in information on a product's origin and processing for both consumers and business partners. Primary concerns with web based tracing systems are information security and the accuracy of self-reported information. Additionally, the web-based system can only trace products throughout the entire supply chain if all companies subscribe to the online tracing service.

TraceRegister

TraceRegister is an example of a self-reporting, online, traceability scheme. The Seattle-based company was founded in 2005 on the basis that seafood consumers should know more about their purchases, and should be able to trust that their purchases are safe and in accordance with the associated label. TraceRegister aims to track the life history of a product in an increasingly complex food system to ensure "integrity and quality" (Trace Register 2009). Members pay a fee for access to the online TraceRegister interface. Restaurant owners, distributors, processors, and other members of a supply chain can see, and therefore choose, the origin of their products. Members enter information about the product at the point in the chain of custody in which they deal with the product. Other members in that chain of custody can follow the product's movement, as well as any inputs to the chain of custody.

TraceRegister traces both aquaculture and wild caught seafood. The user interface incorporates inputs to the aquaculture chain of custody such as feed, treatments, and day and time of catch or harvest (*Figure 4*). TraceRegister works closely with the Aquaculture Certification Council, the Global Aquaculture Alliance, and the Best Aquaculture Practices certification program, to insure uniformity and user-friendly information (Trace Register 2009).

When handling information for wild caught seafood, TraceRegister secures details such as the coordinates of the vessel at the time of catch, fishing license documentation, catch method, and other pertinent information. TraceRegister works with systems currently in place in the fishery and does not have its own tracking numbers, labels, or certifications. Members can upload electronic or paper records onto the website as proof of action, sales, and quotas (TraceRegister 2010).

A system such as TraceRegister's has many advantages. It is a relatively inexpensive way of managing chain of custody information as it bases costs, starting as low as $150 per year to small fisheries, on a sliding scale so it can be affordable to many

different fisheries and members of the supply chain (Kock 2009). Membership is often free to retailers and restaurants and others pay for an annual subscription (Kock 2009). As the system currently exists, no auditors are involved, and there is not need for purchasing new technology. TraceRegister exposes the entire supply chain, thus product differentiation is evident and can be advantageous to those marketing a specific product. The system exposes fraud and other illegal practices, helping to discourage such practices. TraceRegister offers a way to track a product backwards if need be, because of sickness, disease, illegal products, etc.

TraceRegister's system has a number of drawbacks. A major criticism of the web-based system is the lack of a guarantee or third party oversight. There is no overseer incorporated into TraceRegister, as participation is voluntary, and therefore information is only as reliable as its source. Buyers may be skeptical of the accuracy of the information on the TraceRegister website.

TraceTracker

TraceTracker works on a global scale to electronically track product supply chains. The company was founded in 2000 and has offices located in Africa, Asia, Europe, and North America. TraceTracker's seafood related clients include fish feed suppliers, fish farms, wild caught fishing companies, and various seafood importing and exporting companies. The TraceTracker system is currently used to trace these products from their source to the end consumer (TraceTracker 2010).

TraceTracker can trace each stage of production, processing and distribution (Ratcliff and Boddington 2009). The tracing service is primarily marketed as a way to add value through product differentiation, and to diminish risk of a large-scale expensive recall. TraceTracker also facilitates compliance with various government regulation documents, as well as required and voluntary certification documents, by gathering the necessary information for its fishery and seafood clients. These include MSC documents, County of Origin Labeling, Pollution Monitoring, EU IUU regulation, and HACCP compliance (Kittelsen and Altindag 2010). Tracing seafood also allows the entire supply chain, from the wholesale supplier to the consumer, to differentiate between safe and unsafe products (Ratcliff and Boddington 2009). TraceTracker allows product quality to be monitored more closely through the supply chain.

The primary subscriber of TraceTracker is normally the fishery or company that will be associating its brand name or reputation to a fish product. TraceTracker first conducts an analysis of that primary subscriber's record keeping system. Using this analysis, TraceTracker can then systematically pull data from the company's computer system, and input it into the TraceTracker system. In some cases this data comes from multiple sources within the company. TraceTracker then consolidates the information in a central database. This keeps time investment costs low for TraceTracker subscribers (Kittelsen and Altindag 2010).

In order to ensure comprehensive traceability, TraceTracker assigns an identification number to each shipment of seafood that a client purchases. TraceTracker then uses the internal record keeping of the client to trace where the product is sold (Kittelsen and Altindag 2010). TraceTracker's software makes it possible to create comprehensive data that links the internal traceability for multiple companies and the transactions between companies for seafood products (Ratcliff and Boddington 2009). For vertically integrated companies, TraceTracker is able to trace the entire supply chain for a product. However, it is more often the case that seafood products change owners multiple times. In this case, TraceTracker is only able to trace the product if it has contracted with each company involved in the product's supply chain (Kittelsen and Altindag 2010).

Confidentiality of proprietary information is important within the seafood industry. TraceTracker has measures in place to ensure that companies will not be forced to disclose information that will put their economic interests at risk. TraceTracker gives each company the option of how visible the company wants its information to be to consumers and other companies in the supply chain. This allows different information to be provided to different members of the chain of custody. For example, if a buyer needs to ensure that a product has Country of Origin Labeling and HACCP compliance, it is possible for only that information to be made available (Kittelsen and Altindag 2010). Using the TraceTracker online system, a company has the option to make the product history and a map of the catch location for its seafood products available to consumers and clients.

TraceTracker is a subscription-based service and each company that uses TraceTracker must pay a regular fee depending on the size of the company and the volume of information that must be traced. TraceTracker can also design a wholesale contract with a government or association (e.g. fishery association), and that body can assign the share of the costs to its member entities as it sees fit. Thus, it may be the case that the fishers and producers are not charged, or pay only a nominal fee. TraceTracker charges on a sliding scale, so the service can be affordable for both large and small companies. Costs can range from 200 dollars for the smallest fishing company to thousands of dollars for larger companies. A general cost will be approximately 0.05% to 1.0% of the value of the products being traced (Kittelsen and Altindag 2010). Further study is necessary to determine if the profit gained from instituting the tracing system is greater than the initial cost of installation and the annual subscription fee.

All information that a company provides to TraceTracker is self-reported. This means that there is no third party auditor reviewing the accuracy of the information. The absence of third party verification provides the possibility of deception and thus weakens the trust that consumers and other companies in the supply chain will have of the information provided.

Product Tagging

Product tagging can provide information on a seafood product along the entire supply chain. Through this product tagging system, a seafood item's source and handling information can accompany it as it makes its way to the consumer, and information can be added by links in the supply chain. Product tagging can also help seafood businesses market their product to consumers.

Product tagging is one of three tracing systems that we believe to be the most promising and feasible for use in the seafood industry. It allows for monitoring of the location and ownership of a seafood product, making it easier for seafood businesses to inventory products. Tags facilitate ease of information exchange between buyers and sellers. Finally, the presence of a tag or label on a product is a simple and effective way to communicate to consumers that it has been harvested from a responsible source. Alone, product tagging may not overcome all of the obstacles that prevent industry-wide implementation of tracing measures. However, the advantages that accompany product tagging may make this system a key component of a future tracing system.

Fish tagging is a broad term for different styles of marking or identifying fish either for chain of custody traceability or as a way for businesses to track their inventory and reduce liability and fraud. The fishing industry uses tags, or carriers, to identify an individual fish (e.g. a tuna) or a batch of fish (e.g. a bag of scallops) and to help guarantee that a product's source information remains with it throughout the supply chain (Magera and Beaton 2009). The fish may be whole, filleted, gutted, head-on or head-off. Seafood suppliers may utilize a tag for the consumer's benefit to easily identify any characteristic of a fish, such as the name of the fish or where it was caught (Seafood Automation 2010). In Massachusetts, for example, responsibly harvested lobsters are tagged with green rubber bands around their claws to signify to consumers that harvesters of those products are making an effort to reduce the environmental impact of their traps (Associated Press 2008).

Companies offer different types of carriers, of which fisheries can choose a wide variety for chain of custody tracing *(Figure 5)* (Ketchum Marketing, Inc. 2009). Carriers may be simple, plastic identification tags that fishermen can easily apply to the gills of a small finfish, similar to price tags on clothing (Ketchum Marketing, Inc. 2009). Elastic bands or rings can go around a part of a fish, such as the tail of a salmon or claw of a lobster, or around a bag or batch of fish (Ketchum Marketing,

Inc. 2009). These tags may have customized information printed directly on the tag, either by hand or by a computer, or they may have a barcode label (Universal Tag, Inc., 2010). Barcodes require a scanning device, or reader, and, in some cases, computer software for inventory purposes (Magera and Beaton 2009). Radio Frequency Identification tags (RFIDs) store product information on a microchip in the carrier (Magera and Beaton 2009). RFIDs technology is more sophisticated than barcodes because they are reusable, multiple carriers may be scanned at once, and data may be sent to external systems such as graders, trading and order handling systems, or computerized traceability systems (Petersen and Green 2006; Magera and Beaton 2009). Furthermore, tagging systems may be manual, semi-automatic, or automatic. Some tagging companies manufacture tags specifically for a type of fish, such as salted or skin-on fish, portion sized fish, farmed fish, or lobster and crab (Seafood Automation 2010). One Norwegian company is planning to release an all-in-one system that can wash, weigh, tag, and package fresh or frozen fish (Seafood Automation 2010). While tagging offers many benefits in terms of improving product tracing, increasing the exchange of information, and developing consumer confidence and awareness, it does place a potential cost burden on fishermen and seafood suppliers (*see Costs Section*). However, for businesses controlling multiple stages of the supply chain, using carriers to keep track of inventory and product exchange may be very attractive (Arnett 2010).

Costs

Enrolling a fishery into a tracing scheme has many costs. The annual fee for services ranges from a few thousand dollars to hundreds of thousands of dollars for a fishery. Fisheries may have to pay for certification, membership fees, on-site audits, technology, the use of logos, and for other various services (*Table 1*). Often, these costs are confidential between the fishery and the company, and thus the following information is not comprehensive, but rather a sample of costs we are able to report.

Third Party Verification

MSC

The Marine Stewardship Council (MSC) provides their customers with an estimate for costs that is confidential between MSC, the client, and the auditor (MSC, 2010). Customers pay for five services when contracting with MSC: a pre-assessment, a full assessment to receive certification, a re-assessment every five years, a chain of custody assessment, and use of the MSC logo (Macfadyen and Huntington 2007). The baseline cost for MSC certification depends on the type of certification (a fishery or a chain of custody), if the certification is done online or onsite, or if the client is undergoing an initial or annual certification (Nistad 2010). From the baseline costs, the price increases as the time to complete the certification also increases, as the travel distance for the auditor increases, or if there are unanticipated setbacks in the certification process (Accreditation Services International 2008).

Macfadyen and Huntington (2007) found that pre-assessments can cost between $2000 and $20,000, while a full assessment can cost between $10,000 and $500,000. Costs for annual audits are low, unless significant issues arise during the audit. MSC charges fisheries 0.5% of the value of the product for use of their logo on a product, and a minimum charge to cover administrative costs for the use of their logo elsewhere.

One of the factors that increase the costs of MSC certification is the involvement of a certifying body. It is expensive for an organization to become accredited to certify a fishery or a chain of custody—it can range from approximately $3,400 to $21,000 plus costs of travel, food, accommodation, and for annual surveillance, which are paid for by the fishery undergoing certification (Accreditation Services International 2008). MSC receives payment for certifications, and royalties from the use of their logo (ISEAL Alliance 2010; Kock 2009). The certifying body receives the majority of the total cost to a fishery or chain of custody for an assessment or audit (ISEAL Alliance 2010)

Fisheries can decrease costs by being well prepared for an audit, combining audits and assessments with other local fisheries, and combining individual audits and assessments with other members within their chain of custody (ISEAL Alliance 2010). Online assessments may be available to a fishery and are also significantly less expensive than onsite audits because the auditor can cover a large portion of the assessment from an office location (MSC 2009). MSC gives the cost for online assessments by two different independent certifiers as ranging between $1,200 and $1,500 for three years (MSC 2009).

Friend of the Sea

Fisheries applying for a certification sign an audit and licensing agreement with Friend of the Sea at the beginning of the certification process. A fishery pays a minimum first year fee to Friend of the Sea of approximately $7,000 and then pays approximately $4,200 per certified product from the same origin for each subsequent year (Friend of the Sea 2009). The price of the audit may increase with increased complexity of the chain of custody and is repeated every three years for aquaculture and every five years for wild capture fisheries (Friend of the Sea 2009). These prices cover the cost of the audit, use of the logo, participation in one Friend of the Sea event every year (such as a Seafood Expo), and promotional events for Friend of the Sea (Macfadyen and Huntinton 2007).

HACCP

Third party audits are mandatory and regulated by the government for shellfish facilities (Macfadyen and Huntinton 2007). Northern Wind, a scallop distributor, estimates the cost of audits to be between $10,000 and $20,000 annually (Morrison 2009). One private company offering consulting services for HACCP compliance charges $225 per hour per consultant, plus travel expenses (FDA Consulting Services, LLC 2010). An audit can take between one day and two weeks (Friend of the Sea 2009). According to the Global Aquaculture Alliance and the FAO, first year costs for a processor to be HACCP compliant is about $23,000 with an additional $13,000 annual fee each subsequent year (Daniel Lee 2009; Cato 1998). This same report estimated the costs to processing plants due to temporarily closing down a plant to implement and comply with HACCP standards (Cato 1998). For each plant, costs ranged from approximately $3,000 to $6,000 (Cato 1998).

Product Tagging

The price to implement a fish tagging system can vary greatly depending on the type of system in place. A review of the literature suggests that barcodes or RFID tags are

the most common tagging practices for chain of custody tracing. According to Petersen and Green (2006) prices for barcodes and RFIDs are $0.02 and $0.09-0.20 per tag, respectively. However, this does not include the computer systems, readers, and other hardware necessary to use the systems.

SIMBA

SIMBA (Seafood Inventory Management with Barcode Accuracy) is a seafood compliance labeling system created by EDP System Services, Inc. designed to help processors more easily facilitate mandatory labeling of seafood products (EDP System Services, Inc. 2006). SIMBA is a combined barcoding and inventory-tracking product; it allows members in the chain of custody to print barcode labels with a chosen set of criteria while storing the information as inventory (EDP System Services, Inc. 2006). EDP System Services sells SIMBA as a package containing a barcode printer, portable barcode scanners, a touch screen computer for use at the end of the processing line, and various accessories (Falco 2010). The average cost to purchase the system ranges from $15,000-$30,000 (Rob Freeman 2010).

Trident Marketing

Trident Marketing, Inc. uses a tagging system to tag every tuna landed and bought. Trident uses a tagging system similar to SIMBA that costs the company $30,000 to purchase, plus an additional $4,000 for each barcode reading device. The company owner estimates tagging costs to be $.03 per fish. Maintaining the products and hardware slightly increases costs (Sakagami 2010).

Online Reporting

TraceRegister

In our communications with TraceRegister we were given basic information on costs (Furner 2009). The price to use the online system is based on a sliding scale, reflecting the size of the operation at each point in the supply chain, thus distributing the burden of costs throughout. Restaurants or individual boats may be able to receive a free membership to view the chain of custody in which they participate. Other members of the same chain of custody may pay anywhere from $150 to a few thousand dollars.

TraceTracker

TraceTracker's costs vary depending on the size of the fishery or company, and based on the amount of data that must be incorporated into the system. Annual fees start at $200 and can range up to thousands of dollars. TraceTracker charges a fee based on a

percentage of the value of the product entered into the system. Members of the supply chain have the option to obtain a group membership. This allows the entire supply chain to divide the cost among users as they feel appropriate, and pay a flat fee to TraceTracker. In this way, TraceTracker has a similar sliding scale to that of TraceRegister (Kittelsen and Altindag 2010).

Table 1: Costs of Selected Tracing Schemes

Tracing Schemes	Type of cost	Cost*	Reference
Product Tagging	Barcode tagging technology	$20,000 - 30,000	(Falco 2010)
	Barcode reading devices, per device	$4,000	(Sakagami 2010)
	Fish tagging, per fish	$.03 - $1.00	(Sakagami 2010; Petersen and Green)
Online Reporting	Annual fee for a member of the supply chain, association, or government.	Sliding scale determined by the volume of fish being traced and number of attributes added to the database	(Kock 2009)
	Membership fee to access and participate in chain of custody reporting	Free for restaurants and individual fishermen. $150 - $1,000s per member.	(Furner 2009)
Third Party Verification	Initial Fees	$1,000s	(MSC 2009b; Friend of the Sea 2010)
	Online Assessment	$1,200 - $1,500	(Macfadyen and Huntinton 2007)
	Onsite, individual fishery certification	$10,750 - $460,000	(Macfadyen and Huntinton 2007) (Accreditation Services International 2008)
	Group Chain of Custody Certification, Headquarters	$1,000 - $1,500 + $250 - $300 for each site	(MSC 2009b)
	Single Chain of Custody Certification	$550 - $1,000 per control visit	(MSC 2009b)
	Royalties	5% value of product	(Macfadyen and Huntinton 2007)
	Annual fee, per product	$4,200	(Friend of the Sea 2010)
	Annual audits	$10,000-$20,000	(MSC 2009b; Friend of the Sea 2010)
	Consulting for compliance, per hour, per consultant	$225	(FDA Consulting Services, LLC 2010)

A summary of costs for a variety of fish tracing schemes. Prices are estimates and may be converted from other currency.

**Some companies, company representatives, or members of the fishing community that utilize some of these services requested that we keep the information they volunteered anonymous and private. All dollar amounts are based on information we could find, and may be extrapolated to correctly represent our understanding of costs based on communications with members of the industry. Dollar amounts may be "best estimates" from members of the seafood community. Based on our research, we feel all information accurately reflects the costs of the services provided.*

Industry Perceptions

In order to provide Monterey Bay Aquarium with recommendations on the best option for traceability, we needed a way to evaluate both costs and industry perceptions of tracing. To accomplish this, we devised a matrix to evaluate stakeholder perceptions of various tracing systems. Through stakeholder interviews, each person we interviewed was able to systematically express their thoughts on each of the systems, based on questions presented by the matrix. Our goal in creating and using this matrix was to understand perceptions of the industry and evaluate where each tracing system may experience a barrier to implementation. As aforementioned in the report, the tracing systems we considered are: third party verification, online tracing, and product tagging. The characteristics we based our analysis on are: start up costs, ongoing costs, effect on product speed, industry acceptance, confidentiality, and verification and enforcement. Our definition of each of these components is as follows:

Startup Costs

Costs to implement a system may include: purchasing new technology, designing a computer interface, training users, hiring the appropriate staff, and performing audits.

Ongoing Cost

Each of these tracing schemes has costs associated with keeping the system in place. These costs may include: maintenance of technology, salaries of new staff members, annual audits, annual fees, and possible royalties for use of the tracing logo.

Effect on Product Speed

Tracing systems add a component to the chain of custody system and may have an effect on the speed of the product through the supply chain. How the industry views the effect on product speed is important, especially for products that are sold fresh or live.

Industry Acceptance

It is important to evaluate each tracing system based on industry acceptance, and the likelihood of each system being implemented voluntarily. Under this characteristic we analyzed the compatibility with current standards and practices, and whether each system is recognized as a viable alternative within the industry.

Confidentiality

Fishermen, suppliers, and distributors are wary of any tracing system that releases proprietary information from other members of the supply chain. Each of the systems was evaluated based on their ability to provide important information to the public and other members of the supply chain without risking confidentiality by releasing proprietary information.

Verification and Enforcement

In this characteristic we asked industry member if they felt each system is verifiable, and if they had confidence that the tracing system would provide accurate information on products and their supply chains. It is important to understand how much outside monitoring and enforcement will be required in each system to feel it is providing accurate information about the supply chain.

Analysis

Our matrix has been an important tool in furthering our understanding of stakeholder perceptions of each tracing system, and where potential barriers to implementation of each may exist. In our analysis of the three tracing systems we discovered that different fisheries have varying impressions of each system. In order to successfully implement a tracing system, these sometimes false impressions must be addressed by accurately communicating the advantage of tracing to the fishery.

In the matrix below, we summarized these perceptions. In each box we recorded how the industry perceived each category. “Variable” expresses that contacts had different impressions of the category. Boxes labeled “High” or “Low” express that our contacts had similar impressions of the category. For example, Third Party Verification was seen to have low effect on product speed and a high degree of confidentiality associated. In the split boxes we found that opinions were split between high volume, low unit value products and low volume, high unit value products. Overall findings are discussed after the matrix background, and further explanation for the rationale behind the analysis for each tracing system follows the diagram.

	Start-up Costs	Ongoing Costs	Effect on Product Speed	Industry Acceptance	Confidentiality	Verification & Enforcement
Third Party Verification	Variable	Variable	Low	Low Volume: Low High Volume: Medium	High	Medium
Online Reporting	Low Volume: Low High Volume: High	Low Volume: Low High Volume: Med/High	Variable	Medium	Variable	Low
Product Tagging	High	Med/High	Low Volume: Low High Volume: High	Low Volume: High High Volume: Variable	Variable	High

Matrix Results

Startup Costs

Third Party Verification
We found stakeholders that already had some of the requirements for tracing, such as HACCP, were more likely to see startup costs for third party chain of custody verification as low. One of the low volume stakeholders felt that the initial audit would be fairly inexpensive to conduct, however the preparation for the audit would be time consuming. Conversely, one low volume stakeholder and one mixed volume stakeholder that we spoke with did not think that any startup costs would be justified, due to an absence of proven return on investment. We ranked startup costs for third party chain of custody verification as variable because of these conflicting perceptions.

Online Reporting
Industry impressions were variable on startup costs for first party batch tracking. Low volume stakeholders felt the implementation of a self-reporting system would be low. Conversely, high volume stakeholders have the impression that startup costs would be medium to high.

Product Tagging

All of the stakeholders that we spoke with perceived tagging as an expensive tracing system, and many expressed concern that it is simply a cost-prohibitive tracing method.

Ongoing Costs

Third Party Verification

Industry perceptions of ongoing costs for third party chain of custody verification were split. Low volume stakeholders felt that the cost of this tracing system was too expensive. High volume stakeholders felt that this was a reasonably priced system, and the best of the three in terms of ongoing costs. One high volume stakeholder noted that ongoing costs would include company oversight, staffing, funding, and companywide integration. Two other high volume stakeholders perceived that annual audits would be expensive. One mixed volume stakeholder felt that any costs to implement third party chain of custody verification would be too much since there is no proven return on investment. However, this same stakeholder also positively noted that this type of tracing my force internal changes to meet audit requirements.

Online Reporting

Industry perceptions of ongoing costs for first party batch tracking were variable as well. Many low volume stakeholders felt that the cost of this tracing system will be low, whereas high volume stakeholders believe that this system would have medium costs, higher than those associated with third party chain of custody verification. A mixed volume stakeholder and a low volume stakeholder agreed that costs would be relatively low, due to minimal additional staff time and minor internal changes.

Product Tagging

All of the stakeholders shared the perception that the ongoing costs of tagging are medium to high due to the possible technology expenses.

Effects on Product Speed

Third Party Verification

The stakeholders reached a consensus that third party chain of custody verification would not have a significant affect on product speed.

Online Reporting

No consensus was reached for first party batch tracking. Low volume stakeholders felt it would have little to no affect on product speed, whereas high volume stakeholders felt it would slow down product speed. Low volume stakeholders elaborated to say that some products would be influenced more than others.

Product Tagging

Impressions of the affect on product speed were highly split in this category. Low volume stakeholders did not feel that tagging would have a significant impact on product speed, whereas high volume stakeholders believe tagging would slow down product movement substantially, some feeling it would be impossible to implement at an individual product level.

Industry Acceptance

Third Verification

This category was split. Low volume stakeholders perceived low industry acceptance, and felt there is not enough incentive to initiate this style of tracing. High volume stakeholders perceived mid-level industry acceptance. They feel improvement can be made with current third party chain of custody verification systems, but that it is an acceptable approach. One low volume stakeholder stated that third party chain of custody verification tracing would work best for companies that strive to have a corporate culture that emphasizes progress, qualitative as well as quantitative developments within a logistics program, and enforcement from the bottom up. There was a consensus between the stakeholders that third party chain of custody verification would need to be done in accordance with current auditing best practices. Low volume stakeholders expressed discontent with this system because they do not feel it is fair for a fishery to get 'negative points' for not using auditors even if they are sourcing from sustainable stocks. Additionally, all the stakeholders were skeptical about paying for a service that brought in an outside agency to 'judge' their business practices.

Online Reporting

All of the stakeholders felt that adequate industry acceptance exists for this method, but that improvements can be made. A low volume stakeholder noted that for the industry to fully accept this tracing method there must be proven consumer demand and the system must be economically feasible. A low volume stakeholder felt that the extent to which a company was vertically integrated would determine how accepted online reporting would be, especially since this system would be so valuable for a vertically integrated company in terms of inventory control and turnover. A mixed volume fishery stakeholder noted that this system would provide producers a way to differentiate their product and increase market share. The mixed volume stakeholder also responded that first party batch tracking is the most market savvy option, since the system can target specific segments of the market or industry.

Product Tagging

Most of the stakeholders felt this is an acceptable method for tracing, with the exception of one stakeholder who stated that it would be impossible for his company to implement tagging on the individual level, but could potentially see some tagging information on a certain number of products as a group.

Confidentiality

Third Party Verification
For all stakeholders, confidentiality of proprietary information is not perceived to be an issue with third party chain of custody verification. Stakeholders stated that this was not a high concern since clients would sue if any proprietary information were leaked to the public or to competitors.

Online Reporting
This category had varying opinions. Some stakeholders felt that confidentiality was not an issue with first party batch tracking, while others were skeptical of how information would be shared. One stakeholder noted concern about potential leaking of information on clients, suppliers and pricing.

Product Tagging
Stakeholder had varying opinions in this section; with some stakeholders expressing that tagging does not affect confidentiality, whereas others did not feel they could trust the system.

Verification, Enforcement, and Monitoring

Third Party Verification
Some stakeholders feel third party chain of custody verification has acceptable levels of enforcement, while others are concerned with the legitimacy of the current programs that are in place. Because MSC is a well-recognized organization, our contacts often viewed third party tracing as paying MSC certification as well. One stakeholder lacked confidence in the ability for third party monitors to effectively monitor a fishery company and also that there is a lack of strength in verification.

Online Reporting
No consensus was reached in this category. Some stakeholders are wary of the accuracy and honesty of information inputted voluntarily, while others see it as an opportunity to decide how much transparency they want to provide consumers, regulators, and others along the supply chain. One stakeholder noted that first party batch tracking would be a good system to combine with third party chain of custody verification. A stakeholder responded that first party batch tracking would be especially valuable if clearance was given to enforcement officers within the government. A low volume stakeholder expressed uncertainty at how this system would function, but feels that it will eventually become a minimum requirement.

Product Tagging
All of the stakeholders feel that tagging is easily enforced and monitored. One stakeholder indicated that bar code tags would provide the best enforcement.

Important Findings

Based on industry perceptions we came to several conclusions. The first is that industry perceptions vary, and often do not accurately represent reality. This indicates that the some members of the industry may not have sufficient information available to understand the benefits of potential tracing systems. For example, stakeholders had many different perceptions of costs that did not accurately mimic what we discovered in our research. Incorrect assumptions on costs can be a significant barrier to implementation, and it is necessary for companies to understand the true differences in costs between tracing options. Another finding is that perceptions are often split between those who sell high volume and low volume products. For example, sellers of products with high volume often state that tagging would slow down product speed, whereas sellers of products of low volume, such as tuna, do not. With these perceptions in mind, we have highlighted costs and effect on product speed as the two most important characteristics when evaluating a tracing system. Lastly, we found that when we discussed third party verification systems with our contacts, MSC was the main, and often only, company that was mentioned. However, MSC is only available for supply chains that support a certified sustainable fishery and cannot be used for farmed products. These barriers make it unavailable to a large portion of the seafood industry.

Recommendations

Our recommendations are based on information gathered from interviews with seafood industry stakeholders, tracing company representatives, and an extensive literature review. We consider immediate implementation options, followed by actions that can be later taken to augment verification capabilities. This tiered approach creates a new tracing system that entirely uses currently available technologies. The diagram below depicts our recommendations. We start with the most cost effective approach, online reporting, and add third party verification to increase confidence in the accuracy of the chain of custody system that is in place. For certain supply chains, tagging may be necessary in addition to online reporting. This will be discussed in detail, below.

Our first recommendation is that online reporting should be implemented in every supply chain. Online reporting is the most cost effective approach, and provides many benefits to supply chain management. This system can be easily implemented into existing inventory systems as companies can simply input data from current operations. Additionally, online reporting collects all of the chain of custody data into one central location, which allows for easy access to tracing information. This system is useful for companies that wish to provide specific information to different individuals along the supply chain. Online reporting may also be used to provide regulators with necessary information to ensure compliance with current laws. One potential limit with online reporting is that companies that do not currently use electronic record keeping would have to modify their system. Technology may not be available at all points in the supply chain, such as the fishing boat, and information

would have to be collected and passed up the supply chain to a link that has the ability to input data. This can be solved by our second option, which includes adding product tags to the fish in order to capture information prior to database input. Tagging may also be used to enhance management of a supply chain and increase the ease of information entry by linking tags with the online database via scanned barcodes.

As mentioned earlier in our report, there are economic incentives to the seafood industry to alter certain information on products, such as catch method and catch location. Fraud is common with certain products, and in order to have confidence in the supply chain a verification system should be added to both recommendations once the system is in place. This would include third party verification in the form of audits. Without a third party, inputs may misrepresent catch method, catch location, and product movement. This tiered approach of combining tracing systems may provide the industry with many benefits, through both improved management and increased transparency. Benefits of a supply chain with information in one central location include: ease of sharing information along the supply chain, faster response to recalls, ability to share certain information to regulatory agencies, cost-effective management system, and product differentiation. Adding third party verification provides buyers with the confidence in information provided.

With these recommendations, Monterey Bay Aquarium and Santa Monica Seafood can request species that are “Best Choices” and “Good Alternatives” implement tracing, beginning with online reporting, and if necessary product tagging. Products not categorized as “Best Choices” or “Good Alternatives” would most likely not be included in this requirement because they do not have economic incentives to implement a tracing system. Once online reporting, and possibly product tagging, is in place, regular audits can be used to verify that suppliers are actually providing the products they claim to. Audits would not be immediately implemented because we feel an adaptive management approach provides active use of online reporting to confirm our assertion that this system will be cost-effective and useful for management. This tiered approach will give Santa Monica Seafood, as well as other partners, confidence that they are providing consumers with accurate information on the seafood products they purchase. One limit to this system is deciding who bears the cost of the audits. Outside the scope of this project, this should be decided in the agreements between Monterey Bay Aquarium and their partners.

Limitations for Tracing Implementation

Recently, both domestic and international organizations have started discussing the development and implementation of a seafood tracing system. In 2006, Australia began to mandate the "one-up-one-down" method for tracing of seafood (Food Standards Australia New Zealand 2005) and Vietnam is currently experimenting with Radio Frequency Identification technology to track their seafood products (Real 2009). Food and Agricultural Organization of the United Nations included a section on tracing seafood in their Fisheries Technical Paper (Huss, Ababouch, and Gram 2004) and the Marine Stewardship Council acknowledges the importance of tracing and requires the certification of the entire fishery chain of custody as part of their eco-labeling program (MSC 2009). Tracing is also important to, and in the spotlight for, organizations such as Monterey Bay Aquarium and National Center for Ecological Analysis and Synthesis.

However, the majority of the world's fisheries do not include an effective, comprehensive tracing scheme. During our project, we have come across a few key reasons that may explain the lack of tracing implementation. While some of these limitations are inherent to a global industry with the size and complexity of the seafood trade, others may be able to be addressed or eliminated by either private businesses or governments.

Breadth of fisheries

The "fisheries" sector is a broad industry with a wide range of needs. Sustainability may be a universal concern for fishery members, but for some it is environmental sustainability and for others it is business sustainability. Individual fisherman in island nations may catch tuna with long lines and sell their fish on a beach. These individuals have low overhead costs—hooks, lines, and occasional boat repairs. Their cost of living is low, and their gear and the length of the day may limit their catches. On the other end of the spectrum is the scallop fleet that fishes Georges Bank and Grand Bank in the North-West Atlantic. For these fishermen, the size of the boat directly correlates with how many scallops they can harvest; the bigger their engines the faster, farther, and longer they can harvest. They are limited by government-set fishing seasons. They have a high overhead—their boats are costly to maintain, they have a crew to pay, and their cost of living in Canada or the US is high. Their income depends on the prices of fish at auction. Somewhere on the spectrum lie the aquaculture fisheries. These farmers and fishermen have completely different overhead costs: maintaining ponds or cages, providing feed for their stocks, capturing fish, keeping fish healthy and of the right quality for the market, etc. The variety of fishing needs and types of fisheries is a major limitation because of the variety of needs inherent to each fishery.

Diversity of products

The variety of products presents another challenge. Some products, like sashimi grade tuna, are harvested and sold as high value fish and are prized for the quality of the fish. A tracing system for tuna would be valuable to customers, distributors, and fishermen. Distinguishing the sashimi grade tuna from other tuna (e.g. canned, processed tuna) would benefit the members in the chain of custody. The high-grade tuna could be sold at a higher price and a tracing system would provide the buyer with confidence that they are getting the fish for which they pay. Other products, like some frozen, processed, farm-raised shellfish, are harvested, bought and sold for quantity. They make money not based on the high value of their products, but on the large numbers of product that they move quickly along the supply chain. The members of that supply chain may less of an interest in a tracing scheme. These lower value fisheries have little need or desire to distinguish their farm-raised fish from other fish, and could even be at a disadvantage if consumers place a negative connotation on farmed products. The two ends of the spectrum will have different opinions on government regulations, the cost of tracing schemes, and the need for traceability. Again, a single tracing scheme cannot apply to such a wide variety of products.

International industry, global distribution, and political sensitivity

The seafood industry is an international industry, and tracing therefore requires international collaboration. Industries members, fishing communities, scientists, and policy makers must accept a tracing scheme before it is considered reasonable and acceptable on an international level. A tracing scheme should not favor western or eastern styles of business or values, and should not benefit large fisheries over small fisheries, or vice versa. Laws vary among countries for importing fish, further challenging the feasibility of implementing a tracing scheme for the global fishery market. If the US government implemented a tracing scheme, the impact would not be felt globally unless other countries adopted analogous practices.

Lack of incentives

Fisheries will not implement tracing schemes without some incentive. Given the costs involved with volunteer tracing practices (third party verification, product tagging, online tracing), an industry would either need to know they will financially benefit from tracing or have the desire to integrate corporate social responsibility into their business practices. Many fisheries have the potential to fall victim to the Tragedy of the Commons: if other fisheries are not fishing responsibly, it leaves little incentive for one fishery to fish less, to trace their product, or make other similar decisions. Another threat is the free-rider problem—if many fishers are tracing or fishing sustainably, an individual fishery may feel that their non-sustainable practices will not have much of an impact.

Future Research

Costs

Economic data is very important in order to make a fair assessment of different tracing schemes and construct a complete recommendation. During our project we found that finding costs for different tracing schemes proved difficult. In some instances, costs to implement a tracing scheme are confidential between the fishery and the tracing organization. In other instances, the costs encompass numerous players that do not always connect or communicate with each other. Long, complicated chains of custody are less than ideal for determining costs of tagging, such as when members of the supply chain do not share the costs equally. There is little published data consolidating costs for an entire industry, a chain of custody, an individual fishery, or an individual fisherman. Finally, there is a lack of standard operating procedures for many things in the fishing industry, including how to assess costs. Each industry may include boats, distributors, warehouses, etc. with differing technology, languages, and practices. Future research should include a more complete investigation of cost data as it applies to specific fisheries.

Sample size

During our project, we collected data from a relatively small number of representatives from a limited selection of industries. We spoke with individuals from our industry associated with our three case studies, distributors, tracing and auditing companies, as well as other fishery stakeholders. While these individuals provided us with valuable information, it is difficult to assess if the information represents and is applicable to the industry as a whole, or even of those sectors' fisheries. Further interviews should be conducted with a wide range of industry members in order to help form a more comprehensive analysis of the opinions and attitudes of the wider industry.

Data collection

We collected data by interviewing members of the fishing industry. Our data, therefore, represent people's thoughts and opinions, rather than their actions. The data represent opinions of individuals summarizing their industry's practices. While we standardized many of the initial questions we asked, the responses reflect the group member's style and varying follow-up questions, rather than a questionnaire. Future data collection could include a standardized survey that could be sent to many industry members that could collect both demographic and opinion data.

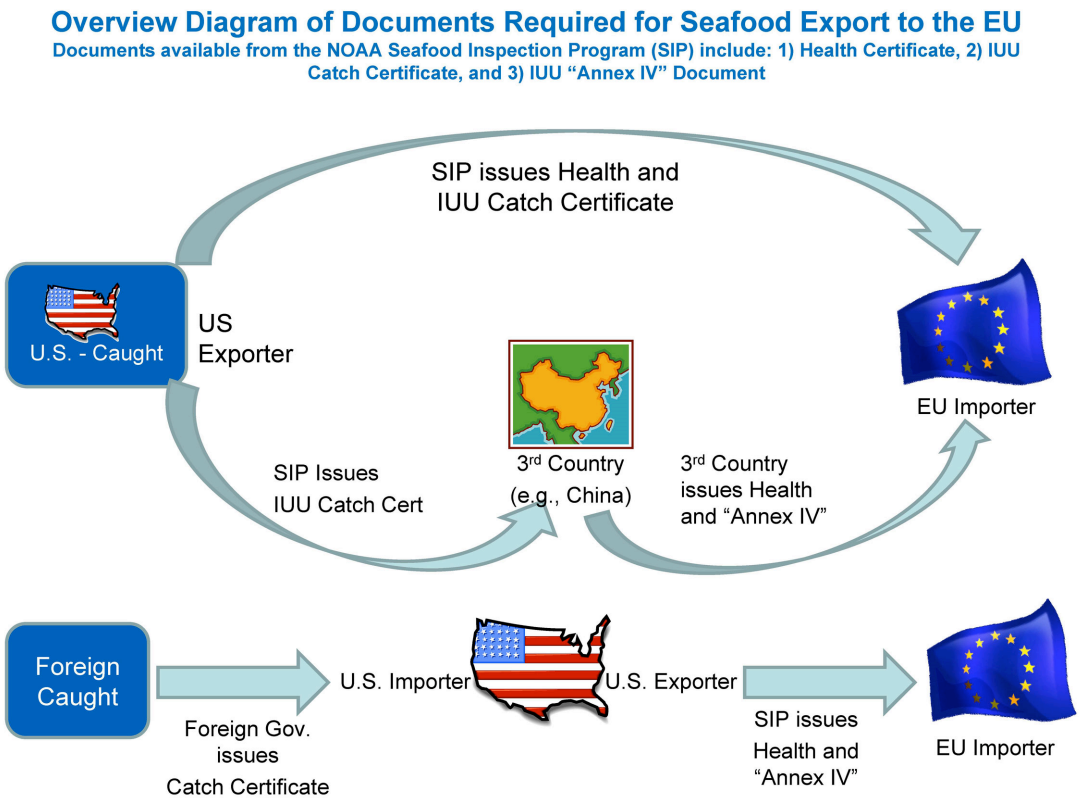
Conclusions

The goal for this report was to determine the best tracing system for Monterey Bay Aquarium and its partners to use in order to provide important information on seafood products to consumers. Through our research, we determined that the two main components necessary in an ideal tracing system were: 1) low costs and 2) verification. Adding verification to tracing inherently increases costs, and thus we believe the tiered approach allows Monterey Bay Aquarium and their partners to establish a full chain of custody tracing system before adding the costs of audits. Once the online reporting tracing system is in place and both Monterey Bay Aquarium and its partners agree it is robust, steps can be taken to ensure accurate data inputs. Through our research, including information gathered from our three case studies and industry contacts, we found a wide variety of opinions among the supply chains of different seafood products, and even between the different members of the supply chain of similar products. Many of these opinions were based on inaccurate perceptions of tracing systems costs, confidentiality, feasibility, and verifiability of available tracing systems. This report provides information to alleviate concerns associated with tracing, including our recommendations, which implement the most cost effective approach to tracing, while including a step to verify the reported information.

This project provides recommendations that increase supply chain accountability, enhance information transfer from the boat or farm to the end consumer, and ensure that Santa Monica Seafood and its customers can trust that products they purchase come from an environmentally responsible sources. Demand for sustainable seafood is likely to increase in the future, both from government and consumer perspectives, and we hope the information and recommendations from our research can be used to help the Monterey Bay Aquarium make tracing an attractive proposition for its seafood partners.

Figures

Figure 1



A NOAA national marine fisheries diagram of the workings behind the new EU legislation requiring catch documents for seafood imported into the EU as they apply to the United States. The top diagram shows that any US caught product sold to an EU importers, either directly or through a 3rd party, requires a catch document. The bottom portion shows that any product imported into the US and then sold to an EU importer must carry the catch document as well. Image is from: *http://www.seafood.nmfs.noaa.gov/EUDocumentsLrg.jpg*

Figure 2

Top Local Seafood	Open Season	Peak Harvest
Market Squid	Year Round	Fall, Winter
Red Sea Urchin	Year Round	All Year
Pacific Sardine	Year Round	Fall, Winter
Northern Anchovy	September-June	Fall, Winter
Rock Crab	Year Round	All Year
Sea Cucumber	Year Round	Summer
White Seabass	June–March	Summer, Fall
Ridgeback Prawn (aka Sweet Shrimp)	October–May	Spring
California Spiny Lobster	October–March	Fall, Winter
California Halibut	Year Round	Summer, Winter
Rockfishes	Year Round	All Year
Swordfish	August–January	Fall
Spot Prawn	February–October	Spring

BEST CHOICES	GOOD ALTERNATIVES	AVOID
Abalone (farmed)	Basa, Swai (farmed)	Chilean Seabass/Toothfish*
Barramundi (US farmed)	Clams, Oysters* (wild)	Cod: Atlantic
Catfish (US farmed)	Cod: Pacific (trawled)	Crab: King (imported)
Clams, Mussels, Oysters (farmed)	Crab: King (US), Snow, Imitation	Dogfish (US)*
Cod: Pacific (Alaska longline)+	Dogfish (BC)*	Grenadier/Pacific Roughy
Crab: Dungeness	Flounders, Soles (Pacific)	Lobster: Spiny (Caribbean imported)
Halibut: Pacific+	Lingcod*	Mahi mahi/Dolphinfish (imported)
Lobster: Spiny (US)	Lobster: American/Maine	Marlin: Blue*, Striped*
Pollock (Alaska wild)+	Mahi mahi/Dolphinfish (US)	Monkfish
Rockfish: Black (CA, OR)	Rockfish (Alaska, BC hook & line)	Orange Roughy*
Sablefish/Black Cod (Alaska+, BC)	Sablefish/Black Cod (CA, OR, WA)	Rockfish (trawled)
Salmon (Alaska wild)+	Salmon (WA wild)*	Salmon (farmed, including Atlantic)*
Sardines	Sanddabs: Pacific	Sharks*
Scallops: Bay (farmed)	Scallops: Sea	Shrimp (imported farmed or wild)
Shrimp: Pink (OR)+	Shrimp (US farmed or wild)	Sturgeon*, Caviar (imported wild)
Striped Bass (farmed)	Spot Prawn (US)	Swordfish (imported)*
Sturgeon, Caviar (farmed)	Squid	Tuna: Albacore, Bigeye, Yellowfin (longline)*
Tilapia (US farmed)	Sturgeon (OR, WA wild)*	Tuna: Bluefin*
Trout: Rainbow (farmed)	Swordfish (US longline)*	
Tuna: Albacore (US+, BC troll/pole)	Tuna: Bigeye, Yellowfin (troll/pole)	
Tuna: Skipjack (troll/pole)	Tuna: canned light, canned white/Albacore*	
White Seabass		

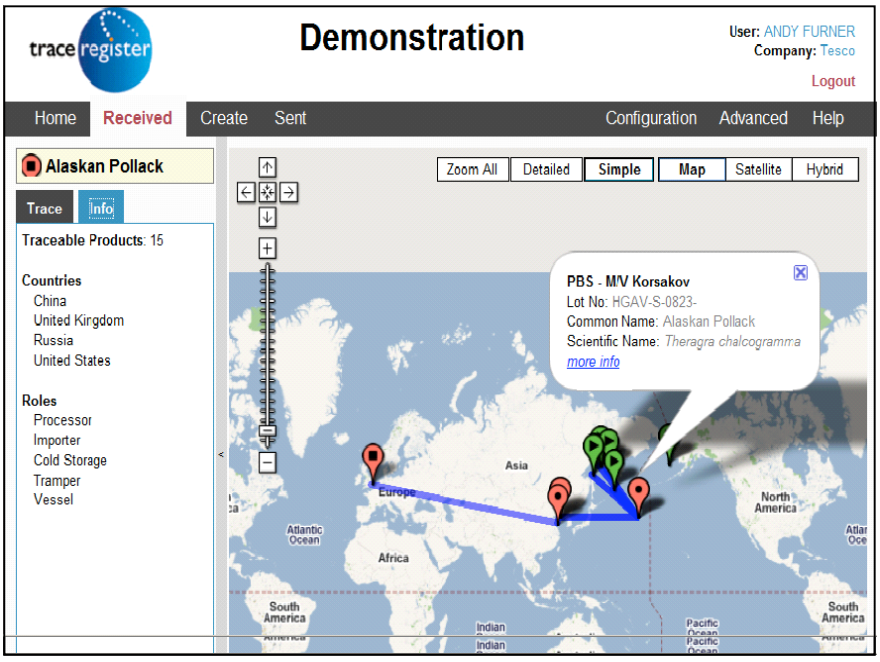
Two different consumer guides that could potentially send conflicting messages. The top guide (Ty Warner Sea Center Sustainable Seafood Program) suggests "Rockfishes" as a top local seafood year round. The lower guide (Monterey Bay Aquarium Seafood Watch) distinguishes between three different types of "Rockfish" that can be a best choice, a good alternative, or a species to avoid. To further confuse matters, the former's "good" column is red, while the red column is to be avoided on the latter's.

Figure 3

- Company Annual Return
- Annual Financial Statements
  Statement of Tax Account from Fiji Islands Customs and Revenue Administration (FIRCA)
- Company Registration
- Letter from FIRCA stating that all tax issues are up-to-date
- Letter from the Reserve Bank of Fiji confirming that the proceeds of all export sales have been repatriated to the country
- Letter from ANZ Bank confirming all remittances from offshore
- All bank statements confirming same

The following requirements must be fulfilled in order to obtain a Fijian fishing license. These regulations are primarily in place to deter IUU fishing. The license application goes before a committee of 14 persons from various Government Departments before the license is approved for another year. Information provided by Melanie Merry of Naturally New Zealand.

Figure 4



This is an example of the user-interface of the TraceRegister website. The different bubbles show different stages of the chain of custody, in this case, for Pollock. Members of the chain of custody can click on any of the bubbles to find information about the Lot Number, the species name, the vessel, the company, or even the feed in aquaculture practices.

Figure 5

A variety of tagging styles used to identify seafood products. Clockwise from top left: T-Bar fasteners and gun for gill tagging; Implant gun for RFIDs; RFID scanner for reading RFIDs; Aluminum live-fish tag. The top 4 images are from Ketchum Manufacturing Inc. catalog. The barcode and barcode printer are from Dynamic Systems, Inc.

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