Development of Live Shellfish Export Capacity in Oregon

By

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Contents

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Executive Summary

Overview

There are many opportunities for seafood exporters to earn substantial profit in Asian markets. The trade in live shellfish exports to China could be especially lucrative. In many respects, Oregon's shellfish industry is well positioned to meet this demand. However, due to certain impediments, interested parties remain largely unable to establish effective means of competing in the Chinese marketplace.

At the request of Oregon Sea Grant, a project was undertaken to provide stakeholders with recommendations for the continuing development of live shellfish export capacity in Oregon. The project was carried out by two investigators in three parts under the direction of Dr. Tim Miller-Morgan, Oregon Sea Grant Extension veterinarian at Oregon State University. Investigations consisted of

- reviews of literature on current live shellfish shipping practices
- research of the prevailing export procedures and the economic and regulatory environments
- visits to sites of special interest and interviews with representative stakeholders

Findings from this joint investigation formed the basis of this report.

Significant Project Findings

Discouragement over prohibitive shipping costs is pervasive among Oregonian shellfish exporters. Offsetting high international shipping costs is challenging due to both high shrinkage (the loss in weight due to dehydration) and low sales volumes.

Stress encountered during transport reduces the quality of live product, and any reduction in quality will substantially reduce the market value of live product. From the time of raw material harvest to the time of consumption, live shellfish are especially vulnerable to rapid (and usually irreversible) degradation.

Chinese seafood buyers demand premium quality. It is therefore imperative that live product destined for this market is passed along the supply chain with a minimal amount of handling in a minimal amount of time. The urgency with which live export product must be moved often results in large numbers of relatively small shipments, impacting economies of scale.

The key problems for stakeholders to resolve include

- refining methods and materials for live transport
- improving logistical capabilities (e.g., establishing export holding facilities)
- maintaining adequate communication between relevant agencies and trade partners (e.g., working together to eliminate regulatory impediments)

Recommendations

While the challenges that Oregon's live seafood exporters face are numerous, they are not insurmountable. Stakeholders should take a comprehensive, unified course of action that addresses each link in the supply chain. If the overarching aim is to promote a general expansion of Oregon's live seafood export industry, additional emphasis should be placed on

- seeking markets for live shellfish products that have limited appeal to domestic consumers (e.g., sea cucumbers)
- developing special, optimized live shipping techniques for each fishery
- creating "brand recognition" for Oregon seafood
- organizing all interests in Oregon for the purposes of (1) gathering/sharing information, (2) consolidating international shipments, and (3) streamlining export regulations/inspections

Introduction/Rationale

The U.S. suffers from a gross deficit in the global seafood trade; its exports account for only $4 billion of the $60 billion annual global receipts, while its imports exceed $13 billion. According to the U.S. Department of Commerce, China is the largest seafood exporter to this country, supplying approximately 1.2 billion pounds of product per year (Fabey, 2008).

Live seafood is becoming popular among China's emerging middle class. This consumer base is very particular about the quality of live shellfish, and is increasingly able, and willing, to pay for premium product.

Therefore, U.S. seafood industry stakeholders could use leverage earned from being China's biggest customer to gain special access to the burgeoning Chinese seafood marketplace. It would seem that the greatest challenge at hand is in delivering product (particularly live shellfish) to these distant markets in the required prime condition.

Ensuring that only top-quality live product is received at the final destination begins in the fisheries. Significant shrinkage has been attributed to the lingering effects of capture trauma (Basti et al., 2010; APEC, 1999). Factors that can affect product quality during the earliest steps of production include

- season (weather, timing of harvest with other activities)
- genetics/sex/life history of individual animals
- specific culture facility/harvest area
- harvest method

Subsequent to being landed, live product is rushed through a long supply chain (Pastoriza et al., 2004). Factors that can affect product quality during the later steps of production include

- method of purification/depuration/purging
- type of packaging
- distribution practices
- retail display environment
- extent of consumer handling

Live shellfish that have been weakened by abuse during harvest, early holding, or initial packing are less able to withstand stressors experienced later in the chain of custody. For this reason, proper holding and transshipping allow time for sufficient physiological recovery prior to and during long-distance shipment. Consequently, the use of holding and transshipping facilities has increased over the last decade. Product that passes through such facilities can be evaluated, inventoried, and repackaged. It may be forwarded to wholesalers, distributors, or even directly to restaurants (Paust et al., 1999; APEC, 1999).

In China, wholesalers who sell directly to retailers receive the greatest volume of imported live shellfish product; distributors seldom handle product. Approximately 65 percent of this is presented to the final consumer in fresh seafood markets, 30 percent in supermarkets or hypermarkets (combination supermarkets and department stores), and 5 percent in restaurants (APEC, 1999).

It is difficult to estimate the size of China's live seafood trade. The sheer volume of product that moves through its ports is overwhelming, and a considerable percentage is known to be smuggled into the country from Hong Kong (Paust et al., 1999).

With some development and organization, Oregon's shellfish producers could compete very effectively in these markets. The purpose of this project was to outline the principle resources that must be developed and organized by prospective exporters.

Background

Practical Considerations for the Export of Live Shellfish

Challenges Associated with Shipping Live Shellfish

An increasingly globalized consumer market demands convenience at budget pricing. The range of "value-added" products has been rapidly expanding to meet this demand. The retail seafood market has been impacted by this trend, hence the recent pervasiveness of consumer-friendly, ready-to-eat seafood products (Wright, 2011; Robinson, 2006). Now, shrimp are likened to popcorn, salmon comes in patties, and crab is a kind of cake.

At the same time, demand for high-end seafood products remains strong. This relatively small but lucrative market demands absolute *quality*. As with any seafood, quality essentially means freshness (Murphy, 2003).

Since "live" is as fresh as it gets, one could reasonably say that live seafood is itself an added value. After all, bringing live seafood to the consumer involves much more than simply not processing it.

Live seafood is also very perishable, and bringing perishable products to market requires expedited transport. Owing to refinements in logistics services and shipping technologies, live seafood is fast becoming an important commodity for both domestic and international markets (Christophersen et al., 2007; Pastoriza et al., 2004; APEC, 1999). Seafood exporters seemingly have the capability to ship any live product to any market that is accessible by land, sea, or air.

Priority cargo transport is expensive. Some products (e.g., crayfish) are rarely exported, as their market prices are typically far too low to justify the high cost of long-distance shipment (Paust and Allison, 2001). To offset transport costs, sellers must obtain premium prices for their product. Accordingly, a pound of fresh shrimp can wholesale for $1.50 to $2.00, whereas a pound of live shrimp can wholesale for $3.00 to $4.00 (Murphy, 2003). Some Asian markets will pay as much as 6.5 times as much for live product, with certain types of shrimp reaching prices as high as $200 per pound (Paust and Allison, 2001).

Long-distance transport is invariably stressful for live product. From the moment it is harvested to the moment it is consumed, live product is subjected to a wide range of stressors. Its resistance to physiological collapse (i.e., its shelf-life) sharply declines as these stressors mount (Christophersen et al., 2007). Stress can lead to significant quality defects, which ultimately reduce market value. It is therefore imperative for prudent exporters not only to minimize product loss due to mortality but also to minimize degradation of product quality due to shipping stress (APEC, 1999).

The effects of chronic stress are more subtle than, but often just as serious as, those of acute stress. Moreover, stressed and unstressed product may look quite similar, at least until a moribund state has been reached (Paust and Allison, 2001; Basti et al., 2010). To most buyers, "live" means more than merely "still moving." As muscle activity can be nonspecific, movement is often possible following the cessation of heart and brain activity. Thus, buyers may rely on specific indicators of physical condition when evaluating live product. In the case of mollusks, this may be a particular muscular reaction, such as the ability to open or close the shell. In the case of crustaceans, it might be gill activity, or a particular response to a physical stimulus (Bremner, 2002; Woll et al., 2010).

While the stress response of terrestrial animals and fish is well understood, the effects of stress on marine invertebrate animals (particularly during storage or transport) remain largely unknown (Basti et al., 2010). To date, a wide variety of live invertebrate animal products is handled and shipped under rather generalized guidelines; these animals are, in fact, frequently subject to similar import/export regulation (Teplitski et al., 2009). Indeed, conventional transport of live invertebrates is essentially the same as it is for any fresh or frozen product, albeit with some important additional considerations (Martin et al., 2000).

Challenges Associated with Transporting Live Shellfish

The terms "shellfish" and "shellstock" are used to denote a diverse group of invertebrate animals that includes mollusks (oysters, mussels, clams, squid, etc.), crustaceans (lobsters, crabs, shrimp, etc.), and echinoderms (sea urchins, etc.). Though they are not necessarily biologically related, there seems to be a commonality in the fundamental physiological needs of all animals in this group (Martin et al., 2000).

However, each shellfish species is physiologically unique and will respond in a unique way to a given set of shipping parameters. It therefore seems reasonable to expect that product will arrive in an optimal selling condition only if it is handled and shipped under optimal (i.e., species-specific) conditions.

Accordingly, working with the anecdotal reports of tradesmen as well as observations from simulated transport experiments, investigators continue to customize live shellfish transport procedure (Christophersen et al., 2007). This requires an understanding of how the shelf-life (as well as more-refined measures of condition such as safe-life, display-life, taste-life, etc.) of each commercially important species is affected by events and conditions along the supply chain (Bremner, 2002).

The long-distance transport of live product can be thought of as consisting of two distinct phases; **handling** and **shipping**. During handling, an effort is made to effect certain changes to the condition of the product (e.g., sorting, cleaning, purging, disinfecting); during shipping, an effort is made to prevent changes in the condition of the product (e.g., maintaining a stable transit environment) (Paust and Allison, 2001; Darbyson et al., 2009; APEC, 1999).

Stressors typically associated with handling include

- emersion (air exposure/not submerged in water)
- salinity shock
- physical injury resulting from capture or interaction with other animals

Stressors typically associated with shipping include

- temperature extremes
- ammonia poisoning

- physical injury resulting from jostling or compression

A great many of these stressors can arise in either phase of transport and are often closely interrelated (Paust and Allison, 2001; Malagoli et al., 2007; Darbyson et al., 2009).

Immediately post-harvest, some product may already be physically damaged by crush forces in the capture device (e.g., trawl net) (Ridgeway, 2007). Open wounds and compression fractures from these types of injuries allow for the loss of bodily fluids and increase the risk of infection (Basti et al., 2010). Many bivalve mollusks (particularly scallops) have fragile shells. If grown on suspended culture systems, some (such as oysters) may have much thinner shells. Cracking or chipping of shell parts can occur if the product is roughly handled. Such defects will not only affect the appearance of the product but can hasten gaping and dehydration (Paust and Allison, 2001; APEC, 1999). Crabs or lobsters can be physically damaged as a result of aggressive and cannibalistic interaction. For certain species (such as the American lobster, *Homarus americanus*), this type of stress is multiplied during certain times of the year when their exoskeleton softens (APEC, 1999). Some species (such as blue crab, *Callinectes* spp.) are so aggressive that interactions can very quickly result in lost limbs and other injuries (Paust and Allison, 2001). Whether they are being transported by the box or in a vivier (live holding) system, claws should be incapacitated (i.e., pegged or bound) (Woll et al., 2010).

Aside from physical damage, the most serious threat to live shellfish product is thermal stress. Wherever multiple factors influence some aspect of the quality of a live shellfish shipment, temperature is almost always the common denominator (Fabey, 2008). Wastage of live product can often be attributed directly and indirectly to inadequate temperature control. The influence of temperature on shellfish health is not always clear. For example, it is now believed that high transit environment temperatures promote cannibalistic behavior in crabs (East and Smale, 2008; APEC, 1999). In addition, damage from thermal stress can be inflicted before the product is packed and shipped. For example, there is a marked decline in the quality of some bivalves (such as scallops) during the warm-water season (Christophersen et al., 2007). Mean air temperature on the day of harvest has also been shown to have a strong influence on the subsequent quality of certain crustacean species (Ridgeway, 2007).

Shellfish exhibit varying responses to emersion. Nevertheless, ambient temperature clearly has a significant influence on the ability of all shellfish to withstand prolonged emersion, which seems to exacerbate a host of physical and physiological stressors (Christophersen et al., 2007; Ridgeway, 2007).

Many shallow-water shellfish species experience emersion naturally (during tidal cycles, seasonal dry periods, etc.) and consequently have acquired a number of physical and physiological adaptations to tolerate air exposure (Danford et al., 2002). The effect of short-term (<4 hours) emersion on these animals will be negligible (Danford et al., 2002; Christophersen et al., 2007). Therefore, intertidal species (such as *Crassostrea* spp. oysters) can survive out of water for as long as one week (APEC, 1999), whereas subtidal species (such as *Pecten* spp. scallops) may begin to exhibit an appreciable amount of stress when subjected to relatively short (~12 hours) periods of emersion (Christophersen et al., 2007).

Though many commercially important shellfish exhibit a strong response to prolonged emersion, dry transport remains the most widely used shipping method due to the prohibitive cost of in-seawater transport. Because of the industry's heavy reliance on this shipping method, much research has been concentrated on this topic. The findings from these studies underscore the need for exporters to understand the unique tolerance of each species to varying conditions (Christophersen et al., 2007).

The main problem associated with the dry shipping of shellfish is, predictably, dehydration. Shellfish suffer from substantial weight loss during dry shipping, largely due to water loss. This is especially harmful to the gills; for proper respiratory and excretory functioning to take place, the gills must remain moist at all times (Paust and Allison, 2001). If a low temperature and high humidity (>70 percent) is maintained within the shipping container, lobsters are known to be capable of surviving 40 hours of dry shipment. In simulated shipping experiments, lobsters exposed to humid air for 24 hours predictably suffered much higher direct mortality than did counterparts in submerged control groups (though a considerable number of subjects in the control groups were sufficiently weakened as to be graded "unsellable," a condition from which few were able to recover) (Paust and Allison, 2001; Tsvetnenko et al., 2001). Another shipping simulation demonstrated that brown crab, *Cancer pagurus*, could easily withstand emersion for 48 hours at low temperatures (2°C and 5°C), with the onset of distress becoming evident after 72 hours. However, at an elevated temperature (20°C), subjects began to show distress after only 12 hours. In fact, these subjects suffered so much delayed mortality that investigators concluded that a shipment in this condition would likely be rejected by the importer (Woll et al., 2010).

At low temperatures, blue crab, *Callinectes sapidus*, will fare much better, surviving emersion for 1 to 3 days (Paust and Allison, 2001). The European green crab, *Carcinus maenus*, is exceptionally persistent, being capable of surviving 2 to 3 days of emersion and up to a week in a small amount of water. Indeed, this highly invasive species is feared for its ability to endure harsh overland transport conditions in trailered boats and boating gear (Darbyson et al., 2009). The survival of live shellfish during dry shipping depends mainly upon ambient temperature and humidity. Oxygen concentration, however, has also been identified as an important factor (Pastoriza et al., 2004).

Under normal circumstances, the maximum concentration of oxygen in water is 5 to 10 parts per million (ppm). Oxygen solubility is higher (whether in seawater or in blood) at lower temperatures. Animals generally will consume between 10 and 1,000 mL oxygen/hour/kilogram body weight. When distressed, their oxygen demand correspondingly increases. Depending upon body size, activity level, and nutritional state, oxygen consumption rates can double or triple with every 10°C increase in temperature (Bubner et al., 2009; APEC, 1999).

Hypoxia can very quickly weaken or (particularly when combined with elevated temperature) even kill shellfish. Simulated live transport experiments have shown that ice provision and oxygen supplementation (i.e., addition of pure oxygen gas to shipment containers) significantly reduced mortality of the abalone, *Haliotis* spp. (Bubner et al., 2009). Similar treatment may be used to reduce gaping in the mussel, *Mytilus edulis* (Pastoriza et al., 2004). It is interesting to note, however, that one researcher found lobster survivability actually decreased with the addition of supplemental oxygen; it is thought that these surprising results were brought about by an unsustainable increase in metabolic rate. Clearly, a better understanding of how transit environment oxygen concentration affects the quality of diverse shellfish species is needed (Paust and Allison, 2001).

Depending upon its particular response to environmental hypoxia, each shellfish species (and indeed all animal species) can be characterized as either conformers or regulators. The conformer's strategy is simply to roll with the punches, allowing its metabolic rate to vary with fluctuating oxygen availability. The regulator's strategy is to maintain homeostasis, employing various mechanisms to limit metabolic change when faced with fluctuating oxygen availability. However, maintaining homeostasis in this way often involves a high energetic cost. Organisms that inhabit relatively unstable (e.g., intertidal) environments tend toward regulation, despite its high energetic investment (Paust and Allison, 2001; Campbell and Reece, 2002).

The distinction between conformers and regulators is only a matter of degree, as few organisms behave strictly as one or the other; often, regulators become conformers when oxygen levels drop to the limiting level of the species (referred to as the critical oxygen level). The critical oxygen level of each species depends upon a number of factors, including its activity level, size, and level of adaptation to environmental instability (Paust and Allison, 2001; Campbell and Reece, 2002). For example, the yellowleg shrimp, *Farfantepenaeus californiensis*, is a regulator under normal oxygen conditions. However, under hypoxic (low oxygen) conditions, it conforms so effectively that it is thought to be capable of tolerating lengthy cargo transport (that is why this species is currently under consideration as a potential fishery for the live seafood trade) (Paust and Allison, 2001).

During emersion, shellfish gills collapse, causing them to stick together like wet sheets of paper. Gill surface area is greatly reduced, interrupting the normal exchange of respiratory gases. Under this condition, the respiration rate of brown crab has been found to decrease as much as 13.6 percent (Danford et al., 2002; Basti et al., 2010; Woll et al., 2010). Even where oxygen supplementation is used, some subtidal shellfish species (such as scallops) may suffer from internal hypoxia due to impaired gill function (Basti et al., 2010). This can be especially problematic during shipping, as the transit environment (particularly if the shipping container is tightly sealed) may become increasingly hypoxic (Pastoriza et al., 2004). Urate, a detoxifying agent for ammonia, accumulates in the blood of crustaceans during emersion (Danford et al., 2002).

Over the course of transport, within the shipping container, carbon dioxide concentration increases as oxygen concentration decreases. Even if an animal’s gills are functioning normally, it can be increasingly difficult to expel carbon dioxide. Upon approaching equilibrium between the animal's internal and external environment, carbon dioxide will eventually cease to diffuse from the blood. High blood concentration of carbon dioxide will lower blood pH. Modulating compounds that accumulate during respiratory distress help to sustain oxygen transport, and can reduce the effect of acidosis by 40 percent. However, progressive respiratory acidosis will eventually culminate in physiological collapse (Danford et al., 2002; Bubner et al., 2009; Sarkis et al., 2005; Woll et al., 2010).

Shellfish, including many crustaceans, respond to air exposure by increasing blood glucose levels; this creates available energy stores that can be utilized in anaerobic metabolism (Woll et al., 2010). When subjected to >30 hours of emersion at <0.5°C, blood glucose levels of the rock lobster, *Jasus edwardsii*, more than doubled (Paust and Allison, 2001). Investigation into the combined effects of elevated temperature and emersion on the lobster, *Nephrops norvegicus*, revealed that these conditions resulted in an increase in anaerobic metabolites that led to an apparently irreversible form of severe physiological stress (Ridgeway, 2007). Investigators have noted that lobsters packed during day shifts had a higher survivability than those packed at night. These differences have been attributed to physiological conditions that vary with circadian rhythms; product packed at different times of the day (i.e., under the control of different hyperglycemic hormone activities) will vary in the extent to which its carbohydrate profile is altered (Paust and Allison, 2001; Ridgeway, 2007).

When oxygen availability has dropped to a critical low point—anoxia—the animal switches from aerobic to anaerobic respiration (Campbell and Reece, 2002). It should be noted that during anaerobic respiration, there is an overall reduction of metabolism in some invertebrates (e.g., bivalves) but not in others (e.g., crustaceans) (Paust and Allison, 2001). Some shellfish, including many crab species, are capable of tolerating anoxic conditions for extended periods of time by way of anaerobic catabolism (specifically, lactic acid fermentation) (Darbyson et al., 2009; Campbell and Reece, 2002). However, as in the case of aerobic respiration, the byproduct of anaerobic respiration (lactic acid) will contribute to a decrease in blood pH (Bubner et al., 2009; Woll et al., 2010). Eventually, this acidosis will reduce product quality. For example, in some mollusks (e.g., mussels), this condition promotes gaping and adversely affects the flavor of the edible meat (Pastoriza et al., 2004). To a certain extent, mild acidosis is adaptive in that it lowers the toxicity of ammonia by converting it to the less toxic ammonium. Elevated concentrations of octopine (an end product of anaerobic metabolism) have an adverse effect on the quality of scallop meat (Christophersen et al., 2007).

Ammonia, the chief nitrogenous waste product of live shellfish, is continuously produced and must be continuously excreted through the gills by diffusion. Shellfish will release ammonia for hours after having been fed. Shrimp can release significant quantities of ammonia 16 hours after eating (Paust and Allison, 2001; Basti et al., 2010). Stress will affect the rate of ammonia excretion. Simply moving product from one container to another, a procedure lasting approximately 1 to 2 seconds, has been observed to cause a 2 to 4 times increase of ammonia excretion in blue crab, requiring 2 to 4 hours for the animals to return to a normal state (Paust and Allison, 2001).

Gill impairment and/or elevated environmental ammonia concentration inhibits the release of blood ammonia to the environment, allowing it to accumulate within the animal. This causes further damage to gill tissues and can, if left unabated, ultimately lead to mortality (Paust and Allison, 2001; Basti et al., 2010; Woll et al., 2010).

Shellfish produce a variety of metabolic products while under stress; these include glucose, lactate, urate, and various hormones (Paust and Allison, 2001). Variables such as temperature, humidity, oxygen concentration, pH, and ammonia concentration have combined effects on a live product's metabolism, as well as its ability to withstand stressors such as physical abuse, hypoxia, and disease. Not only are these combined effects complex, but they may impact the quality of live product in many ways, oftentimes with significant differences between species (Paust and Allison, 2001). Given the economic value of live shellfish exports, such differences are not immaterial; if absolute quality is to be pursued, live shellfish product must be handled and shipped under the most favorable conditions of each species.

Procedures for the Transport of Live Shellfish

A great deal of handling is necessary to move live product along the supply chain. Live product must withstand a diverse set of stressors as it passes through harvest, holding, purification, packaging, distribution, and retail display to consumption (Basti et al., 2010; Pastoriza et al., 2004). The use of inferior materials or the application of improper procedures during any stage of production can exacerbate these stressors, so appropriate holding care, premium packaging, excellent logistics, and high transport speed are essential (Fabey, 2008; Basti et al., 2010; East and Smale, 2008; Pastoriza et al., 2004).

To ensure that a high-quality product is received at the final destination, live shellfish are often held for some time prior to shipping (Paust and Allison, 2001; Martin et al., 2000). Some facilities may hold a million pounds of product at a time (Paust and Allison, 2001). Holding may be out-of-doors. California spiny lobster is kept only briefly in live boxes, from which they are usually taken directly to market (Martin et al., 2000). Oysters that are harvested from perpetually submerged beds may be "hardened" (mainly to prevent gaping) by exposing them to periods of dry conditions in the intertidal zone for up to 3 weeks (APEC, 1999). Lobsters may be held for very long periods of time in large, 3-sided embayments incorporated into the shoreline (i.e., ponds) at very high densities (up to 11 lobsters/m^2) (Basti et al., 2010).

Holding is generally accomplished indoors in holding tanks. These tanks are often highly controlled environments designed to minimize physical and physiological stress to the product and fitted with biofilters, refrigeration units, etc. (Paust and Allison, 2001; APEC, 1999). In such tanks, product can be closely monitored for health. While some exporters may hold product for months, usually in anticipation of peaks in market value, most hold product only for 2 to 4 days for conditioning (Paust and Allison, 2001; Basti et al., 2010).

Conditioning regimes prepare product for the rigors of transport. This often involves purging and/or chilling. The primary purpose of purging is to minimize the discharge of waste (e.g., ammonia) during transit. Purging is accomplished by fasting, but not starving, the animal; fasting involves withholding food just long enough to clear the animal's gut, whereas starving involves withholding food long enough to cause a general breakdown of the animal's physiology. While product that has been properly purged will undoubtedly ship better, the holding process itself incurs weight reduction that ultimately affects the selling price. For example, lobsters (which might be held for relatively extended periods of time) can easily be starved; starvation is counter-productive, in that the animal is weakened, muscle is digested, and ammonia is produced anyway (APEC, 1999).

Chilling is accomplished through a controlled reduction of body temperature (Paust and Allison, 2001; Bubner et al., 2009; APEC, 1999). In some cases it is preferable to chill product (e.g., crabs) slowly, whereas in other cases rapid chilling is best. Two similar species, the black tiger prawn and the giant freshwater prawn, illustrate these differences. Black tiger prawns are very gradually (4 to 6 hours) chilled to a temperature no lower than 18°C, just after about 2 days of fasting; giant freshwater prawns are very quickly chilled to approximately 15°C, just after a good feeding (Paust and Allison, 2001; APEC, 1999). The primary purpose of chilling is to decrease oxygen consumption during transit by reducing metabolic rate.

Shellfish, particularly if subjected to emersion after harvest, will release accumulated ammonia upon placement in holding tanks. This is a common occurrence with crabs, which may accumulate very high concentrations of ammonia within 4 hours of emersion, only to release this excess within 1 hour of re-immersion. This release can result in spikes in ammonia concentration within recirculating holding systems, effectively prolonging product exposure. Hence, heavy stocking of holding tanks may call for the use of materials that absorb, utilize, or detoxify ammonia (Paust and Allison, 2001).

Optimal holding duration varies between species. Typically, resumption of normal oxygen consumption and carbon dioxide off-gassing will occur if product is left undisturbed in holding tanks for 48 hours (Basti et al., 2010). Live shellfish are commonly held for short periods of time post-harvest to undergo depuration, a process by which product is rinsed and decontaminated in clean seawater just prior to shipment (Teplitski et al., 2009). Crabs should be purged for approximately 24 hours (APEC, 1999), shrimp are purged for approximately 2 days (Paust and Allison, 2001), and abalone is usually purged for 2 to 4 days (Paust and Allison, 2001; Bubner et al., 2009; APEC, 1999).

Shellfish should not be fed during cold-water acclimation. The target acclimation temperature is that which will be maintained in the transit environment (Sarkis et al., 2005). Live shellfish (excluding tropical and subtropical species) are commonly held, transported, and stored at 2 to 7°C (Martin et al., 2000). Temperate lobsters become inactive at <4 to 6°C, while tropical species become inactive at <17 to 18°C (Paust and Allison, 2001

Product (particularly sensitive shellfish such as shrimp) might be brought from holding to packing areas in aerated transportation coolers (Paust and Allison, 2001). Packing should be carried out as quickly and efficiently as possible to limit handling time and heat absorption (Martin et al., 2000; APEC, 1999). Packers should be careful to avoid overpacking the shipping container. Even the arrangement of individuals can affect the quality of live product (Martin et al., 2000; Bubner et al., 2009). Packers should be fully aware of a client's specifications regarding product handling, size grading, packing style, and packaging system; this will help to ensure a good price (APEC, 1999).

The seafood and cargo industries continually seek technological innovations to make packaging systems safer, easier to use, and more cost-effective. Increasingly, packaging is being developed to meet the particular needs of each fishery and each target market. Superior packaging systems not only withstand the usual rigors of long-distance shipping (leakage, shock, vibration, stacking compression, etc.), but are also comprised of lightweight materials to minimize shipping costs.

Conventional live product packaging systems consist of a molded foam box within a corrugated carton (APEC, 1999). The outer box is made from either cardboard or fiberboard. In premium systems, this material may be wax impregnated and multi-walled, and reinforced with fan-folded corners. General guidelines for corrugated box wall thickness suggest (1) 4.8 mm for <10 kilos of package weight, (2) 7.0 mm for 10 to 20 kilos of package weight, and (3) a double wall with outside support for packages exceeding 20 kilos of weight. Packaging should be able to withstand stacking of at least five units (APEC, 1999).

Transport time can be extended significantly by reducing the metabolic rate of the product; this can be accomplished by maintaining a reduced transit environment temperature (APEC, 1999). Non-refrigerated packaging systems shield temperature-sensitive product from environmental heat by way of thermal insulation and cold provision (East and Smale, 2008). Materials used for thermal insulation include (in increasing order of insulating ability) double-walled corrugated carton, shredded paper, expanded polystyrene, and urethane foam (Martin et al., 2000; APEC, 1999).

Expanded polystyrene (i.e., Styrofoam) boxes are the most common inner component of live product packaging systems. Though it is bulky, fragile, and potentially expensive to dispose of, its low weight and excellent thermal insulating capacity have resulted in widespread use throughout the industry (APEC, 1999). Expanded polystyrene box wall thickness ranges from 15 mm (6-kilo box) to 25 mm (25-kilo box). In addition to thermal insulation, an expanded polystyrene box provides additional structural support to the package. The thickness of insulating material can be reduced by the use of metallic surface foil, which reflects 97 percent of radiant heat (APEC, 1999).

Cargo carriers do not consider expanded polystyrene waterproof, as it is fragile and may easily break from rough handling. Thus, the 25-kilo unit is the largest expanded polystyrene box that certain air cargo companies will accept, unless it is reinforced with an outer carton. For an added measure of protection from leakage, box liners and absorbents are frequently recommended (Martin et al., 2000; APEC, 1999). Liners may be used inside or outside the molded foam box. Though they are more susceptible to puncture, polyethylene liners are generally preferred to vinyl chloride liners because of their water tightness, high strength, and low cost (Teplitski et al., 2009). Polyethylene bags used for this purpose should be at least 4 mm thick; certain air cargo carriers, however, require a thickness of at least 9 mm (APEC, 1999). There are numerous types of materials used as absorbents. Highly efficient absorbent pads with organic gel agents are available. However, recycled materials such as newspaper and wood shavings have been used with success (Teplitski et al., 2009).

Stuffed under the box liner, materials such as wadded newspaper can provide additional cushioning (APEC, 1999). This helps to prevent puncture of the box liner by sharp claws, shells, and spines (Martin 2000). Materials such as newspaper, rags, mesh netting, and sponge are frequently used as padding within the package. These materials may be moistened with just enough water to keep the product hydrated (Paust and Allison, 2001; *Restaurant Business*, 1993; APEC, 1999). When properly chilled, shrimp (e.g., Karuma shrimp, *Penaeus japonicus*) can be successfully transported in a special type of sawdust (Paust and Allison, 2001). The use of seaweed for padding material is strongly discouraged; aside from being potentially invasive, seaweed releases heat and toxic compounds as it ferments (Paust and Allison, 2001; APEC, 1999). Live product should be padded only lightly, allowing for adequate ventilation throughout the transit environment (*Restaurant Business*, 1993).

Shipping containers are sometimes fitted with ventilation holes at the top edges of the packaging system. Live product packed in ventilated packaging systems should not be stacked as high as the ventilation holes (APEC, 1999). In cases where no ventilation holes are present (and boxes must be sealed), the addition of pure oxygen gas is advised (Martin et al., 2000).

Studies have demonstrated that the use of modified atmosphere packaging (MAP) technology can improve the appearance of live bivalves and extend their shelf life by 48 to 72 hours (Pastoriza et al., 2004). MAP normally is used to *reduce* oxygen content (i.e., to keep dead seafood fresh); however, new applications that *increase* the oxygen content of live seafood packaging are being developed and are awaiting FDA approval (Bremner, 2002; Kramer, 2009). The use of an oxygen-saturated atmosphere has been shown to significantly increase the transport survival rate of Pacific calico scallops, *Argopecten ventricosus* (Christophersen et al., 2007). In one study, the mortality rate of abalones increased by 85 percent when packed with ice and 100 percent oxygen gas (Bubner et al., 2009). Use of oxygen gas has been shown to increase the storage life of live mussels by up to 100 percent (Pastoriza et al., 2004). In addition to preserving the quality of perishable product, MAP allows for an overall reduction of packaging material (Kramer, 2009).

Transit environment temperature is affected mainly by (1) the specific type of packaging system used, (2) the mass of the product, and (3) the initial temperature of the product (APEC, 1999). Pre-chilling the packaging prior to packing will prevent product from absorbing heat from the packaging materials themselves (Martin et al., 2000). The initial temperature of the transit environment has a considerable effect on the efficiency of coolants (East and Smale, 2008).

Cooling can be supplied by the use of ice (wet and dry) or frozen gel packs (APEC, 1999). The use of wet ice is strongly discouraged, and is prohibited by some airlines. If used, it should be tightly sealed in double polyethylene bags. Likewise, the use of dry ice is permitted only by certain carriers, and even then only with prior approval. Obviously, dry ice should not be allowed to off-gas freely within the container (Martin et al., 2000; APEC, 1999). Gel packs are generally regarded as the best coolant, as they have a very high cooling capacity for their weight and volume, cannot easily leak from packaging, and usually can be reused. A typical, pre-chilled expanded polystyrene box, 60x30x40 cm, can maintain a transit environment temperature of 14°C for up to 20 hours using four standard gel packs (Sarkis et al., 2005). Coolants should be placed on both the top and bottom of the shipping container. Poor placement reduces efficiency (Martin et al., 2000). Cool air should be able to freely sink as warm air rises within the container, preventing thermal stratification (APEC, 1999). Any thermal stratification that exists within the transit environment will occur at the interface of three zones: (1) product and void space, (2) the insulation material, and (3) coolants and coolant dividers (East and Smale, 2008).

Coolants should not be allowed to have direct contact with live product. The use of newspaper, soft foam sheets, burlap, etc. can be a baffle between coolant and product (APEC, 1999). Similarly, a false bottom made of drilled polystyrene panels can be used for this purpose (Sarkis et al., 2005). Additional dividers and coolant can be added at the top of the container just before it is sealed (Martin et al., 2000).

Each package should be sealed by at least two bands. Most carriers require at least two bands per package (Martin et al., 2000). Bands are preferred by shippers, as they are simple to attach and cannot physically damage the product (APEC, 1999).

It is critical to determine early on that (1) the chosen packaging system will be accepted by the carrier, and (2) weight limits on unit packaging will not be exceeded. In selecting a carrier, dependability and speed are of much greater concern than price; live product should travel by the fastest and most direct route available. Despite the fact that most air cargo ostensibly has a high "time-value," it has been estimated that only about 8 percent of air cargo shipment time is spent airborne, with about 80 percent of the time spent in wait (Leung et al., 2000). Ideally, product will reach its final destination during a time of day at which it can be processed and released by customs as quickly as possible (Bubner et al., 2009; APEC, 1999).

Cold chain failure is a source of substantial economic loss (East and Smale, 2008). High temperatures negatively impact the health (and value) of live shellfish and may create a health hazard by promoting the proliferation of potentially pathogenic microbes (Pinto et al., 2006). Therefore, cold chain performance of potential cargo carriers and handlers is of utmost importance to those who deal in any perishable product (Fabey, 2008).

Planning for the smooth transport of live seafood can be complicated and generally difficult. Exporters frequently rely upon logistics providers and freight forwarders to "tighten up" the cold chain (Fabey, 2008). Logistics services arrange for the movement of goods between raw materials suppliers, producers, and consumers. Organization and communication skills are essential for those entrusted to carry out this task. Freight forwarders may be involved in packing/repacking, handling/shipping, customs clearance, insurance, bookings, warehousing, and inventory control. Related responsibilities include labeling, tracking, and inspection (APEC, 1999; Leung et al., 2000).

Supply chain management (SCM) involves working with all relevant players—both upstream and downstream—to provide a superior product at a minimal operational expense (Bremner, 2002). It is very important that the transport of any perishable product be carried out in as transparent and seamless a manner as possible. Traceability is critical; in addition to records of any prior transport, this involves an account of the product's origin in addition to any processing history. Modern computerized information systems have allowed much greater efficiency throughout the supply chain (Leung et al., 2000). This has not only facilitated traceability but has also increased the speed of movement through the supply chain. Due entirely to the expediency of online auctions, distributors may now purchase live product before it has landed (Bremner, 2002). Still, despite much extensive technological and operational advancement, certain challenges remain for live seafood enterprises that aim to compete in distant markets.

Current Practices for Shipping Live Shellfish from Oregon

Preparing live shellfish for international shipping is a multi-step process that involves intricate logistics, time considerations, and certification procedures.
Based on information collected from Dungeness crab and Pacific oyster producers along Oregon's coast, we determined the current strategies for transporting these commodities. Following are the essential elements of the process.

Regulatory Bodies

- **Oregon Department of Agriculture (ODA)** is responsible for regulating and licensing commercial shellfish aquaculture operations, leasing land for aquaculture, inspecting all seafood processing and receiving facilities, and approving plans to build or renovate those facilities.
- **Oregon Department of Fish & Wildlife (ODFW)** regulates the Dungeness crab fishery, issues commercial boat and individual licenses, and deals with fishery permits.
- **U.S. Food and Drug Administration (FDA)** operates the National Shellfish Sanitation Program, which provides current standards for aquaculture and guidance on developing a HAACP plan.
- **NOAA's National Marine Fisheries Service (NMFS)** division operates the Seafood Inspection Program (SIP), which provides import and export health certificates for shellfish, facility auditing, and HAACP consultations (e.g., oysters are inspected/sorted based on size in preparation for packaging).
- **U.S. Department of Agriculture** provides disease outbreak information and economic outlooks for aquaculture.

Holding

- Product must be immediately transferred to appropriate holding containers after harvest.
    - Dungeness crab are held outdoors in water-filled, aerated, non-recirculating, flow-through totes until shipment.
    - Pacific oysters are processed, quality checked, packaged for shipment, and placed in a cooler upon harvest.
- Purging is sometimes required, which entails leaving the shellfish in water—with or without treatment chemicals—for up to 24 hours to expel waste.
- For both commodities, employees conduct regular salinity, temperature, and dead loss testing—checking all holding containers to make sure that fewer than 5 percent of the crabs have perished—to ensure quality control.
- Once a producer receives an order, a refrigerated truck is scheduled to transport the

product to the packing (crab) or shipping (oyster) facility.
- The Styrofoam box is sometimes placed in a cardboard box for added security.
- Transit time to the major ports: Seattle, WA (4 to 9.5 hours), Portland, OR (1.5 to 7 hours), or Vancouver, Canada (7 to 12 hours).

Packing

Three major considerations when packing **Dungeness crab** include:
- **Moisture**: The crabs require a constant source of moisture to keep their gills wet and functional; thus when preparing boxes for shipment, an absorbent pad soaked with seawater is placed on top of the product.
- **Refrigeration**: Packed in an insulated Styrofoam or corrugated plastic box lined with reflective material, two gel packs are included at the bottom and top of the box to maintain optimal holding temperature.
- **Oxygen**: Injecting the box with oxygen is an optional part of the packing process, decided upon by the producer—this can help to calm the crabs and increase their longevity.

Similarly, **Pacific oysters** require the following:
- **Insulation**: Fall through spring, the oysters are packed in corrugated wet-lock boxes with a liner to prevent leakage, in summer, a Styrofoam box is used to prevent damage from heat.
- **Refrigeration**: Only one gel pack is required to maintain holding temperature.
- **Moisture**: A damp towel is placed in the box to create a moist, humid environment.
- The final package is banded and can vary in weight depending on the size of the order and the oyster.

Inspection

- ODA inspects growing and processing facilities quarterly and grants operating licenses to growers, harvesters, and wholesale and retail merchants to determine whether they are fit to operate.
- NOAA inspects and certifies all shellfish packaged for international export and ensures all imported seafood is properly certified and in compliance with health regulations. Inspection may occur at any point in the packaging/shipping process.
- There are two options for NOAA inspections: lot inspections or becoming a SIP Program member.
    - Lot inspections require the producer to schedule a time and place for a NOAA inspector, who charges an hourly fee, to verify the health of the product within 24 hours of the product's scheduled shipment.
    - SIP Program members are able to ship specific products to specific countries without lot inspections if they meet export standards for NOAA and the country of import. Participants must pass a rigorous facility and process inspection procedure and submit to regular facility inspections.
- Standard metal containers are used to ship cargo on passenger flights.

Finalizing Shipment

- All shipments must include a NOAA Export Health Certificate.

- Typically, carriers require a freight forwarder to coordinate and book space on any given passenger or cargo flight for a producer's container.
- Product is ultimately inserted into containers and uploaded onto the aircraft.

Additional Key Points

- Live Dungeness crab is a time-sensitive commodity that requires prompt transport and minimized handling to retain quality.
- Pacific oysters are less time sensitive but still require careful handling to reach their destination intact.

Barriers Impeding the Expansion of Live Seafood Exports from Oregon to Asian Markets

According to the Global Trade Atlas, U.S. exports of live crabs to China grew by more than 550 percent from 2009 to 2010 (USDA, 2010). The demand for live seafood is growing exponentially in the Asian marketplace due to increased economic prosperity throughout major Asian capitals. These economic changes have given consumers the means to afford higher-value goods, such as live shellfish exported from the United States.

In 2010, the Marine Stewardship Council certified Oregon's Dungeness crab fishery as sustainable. Due to specific catch regulations and limited entry permits, the state has been able to maintain Dungeness crab stocks and is in a perfect position to supply some of the demand coming from China and surrounding countries. Additionally, oyster aquaculture throughout Oregon has the potential to become a major source of Pacific oysters to China.

However, there are some issues preventing Oregon Dungeness crab and Pacific oyster producers from taking advantage of this opportunity. There are four major barriers to the expansion of the industry.

Weak Infrastructure in Oregon

Producers in Oregon struggle to bring their product to the international market because of weak transportation links. The Port of Portland currently has very few international carriers and direct flights to Asian hubs. As of September 2011, Asiana Airlines (a subsidiary of Korean Air) offers direct service from Portland to Seoul. In the past, however, many Asian carriers have pulled out of Oregon because of a lack of cargo and passenger traffic. If volume does not increase out of PDX Airport, the port may lose this recently acquired international carrier.

Since there are limited options to ship directly from Oregon, most producers must transport their product to Seattle or Vancouver, Canada. These ports host significantly more international carriers and flights, as they are larger hubs. Unfortunately, when using carriers outside of Oregon, producers must design an even more precise logistics scheme that takes into account the time sensitivity of the product, especially in regard to live Dungeness crab.

Refrigerated trucks are used to transport the shellfish to either packing or shipping facilities, based on how the product leaves its original facility. While Pacific oysters can be processed and packaged immediately upon harvest, Dungeness crabs are much more perishable. They should remain in a high concentration of water or ice in containers that can circulate water to remain healthy before packing. Trucks must be equipped with air circulation systems and functional temperature controls to ensure the product remains at an optimal temperature.

Most of the shellfish harvested in Oregon is shipped out of Seattle, Washington, or Vancouver, B.C. Consequently the shellfish must endure between 4 and 12 hours of travel, which can significantly reduce the quality of the shipment.

Inspection Inefficiency

Health certificates are required for any seafood product being exported from the United States. When shipping to China, the only certificates that authorities will accept are those issued by NOAA's Seafood Inspection Program (SIP).

Many producers and participants in Oregon's seafood industry have identified the process to obtain certificates as one of the biggest impediments to shipping internationally. This is due to high and erratic costs, difficulty in scheduling inspections, and the additional handling that often occurs during inspection.

Most NOAA inspectors are located in Seattle, far away from Oregon's coastal harvesters and producers. The NOAA SIP charges an inspection rate in excess of $200/hour. If a producer along the coast wants to have its product inspected before packing, it is charged from the moment the inspector begins travel to the producer's facility. Thus, most exporters prefer inspections to occur at the port facilities, as shipments must be certified within 24 hours of its scheduled international departure. Another reason many producers choose to ship out of SeaTac Airport in Seattle is the proximity and volume of inspectors to this port, helping to reduce the cost of inspection.
For small crab and oyster producers, this poses several problems. Every time a shipment is inspected, the amount charged can vary based on weather conditions, traffic delays, and even the NOAA inspector's schedule. This prevents producers from quoting overseas customers an accurate price, which can decrease sales.

Larger producers can pay a very high flat fee and become SIP members. This requires regular facility inspections and the company entering an audit cycle, but ultimately it results in the ability to generate a health certificate without a lot inspection. While this is a good option for seafood producers with enough volume to absorb the fixed cost, most producers along the Oregon coast are small and can't afford to enter the program.

Due to the erratic nature of inspections, they can occur at any point before the product is loaded onto its flight. This means that once a product is packed and ready for shipment, if the inspector has not seen the crab or oysters to verify that they're still alive, some of the boxes must be opened. This increases handling and stress of the product (especially of Dungeness crab), and can also release oxygen from shipments (if oxygen was included during the packing process).

Lack of Critical Mass

Oregon's coast is dotted with many small, independent seafood producers who together produce a significant volume of shellfish. However, they do not, as individuals, have the resources to efficiently supply international consumers. Shipping internationally is a costly endeavor; there is no way to cover the cost of harvest, packing, inspection, and shipping costs without high export volume.

The sustainability of the Dungeness crab fishery is attributed to many things, one of which is limited entry commercial permits. Currently there are 428 permits in the fishery and no new permits are being issued. While they are transferable, anyone looking to enter and fish a significant volume must find multiple participants willing to sell permits, which is quite difficult. Also, many producers in Oregon have chosen to avoid
International export altogether and focus on the domestic market. If a large number of permit holders are unwilling to consider expanding to the international market, there will be much less volume to contribute to Asia's demand.

Cultural and Language Barriers

The final issue that Oregon's producers must overcome is how to communicate with potential international customers and understand the expectations of those customers in terms of live imported product.

Clearly there is a difference between the tastes and preferences of the American and Asian consumer. Product type, quality standards, and size are all considerations that producers in Oregon must weigh before exporting product to China or other Asian countries. In the United States, smaller Olympia and Kumamoto oysters are preferred over larger Pacific oysters. However, buyers in Asian markets demand the largest oysters the supplier can harvest.

Quality is another important factor to consider, which is based on the personal relationship between supplier and buyer. Once the expectations for the health and condition of the product are in place, a producer in Oregon can expect to have a shipment of Dungeness crabs or Pacific oysters returned if the product does not meet those expectations. It is important to have a strong relationship with buyers, because the inability to provide the volume and quality of product expected will result in lost business.

It is particularly difficult for American producers to form these relationships, because of a lack of cultural understanding and difficulty communicating due to language barriers. Those who wish to become successful in this industry must equip themselves with knowledge of the Asian marketplace or connect with someone who can bridge that gap.

Project Findings and Recommendations

Suggestions for Improving Oregon's Seafood Export Industry

Oregon has the resources to compete in Asia's thriving consumer market but must overcome certain key issues to fully realize that potential. Following are suggestions for improving Oregon's ability to export live seafood internationally.

Develop an International Marketing Coalition

Small, independent producers on Oregon's coast have the ability to grow and harvest high-quality oysters and crab but lack the means to receive the highest price. Consumers in the Chinese market are willing to pay top dollar for live seafood, given that it meets their size and quality standards. Clearly, there is a missing link to bring suppliers together with these eager consumers.

An international marketing coalition, formed through the cooperation of many small producers and the help of the legislature, would create a way to address this and many other issues.

The high cost of shipping seafood internationally is difficult for a single producer to bear, but if a coalition is formed, the opportunity to pool resources and volume can significantly lower those costs. The opportunity to build a single processing facility and to share the cost of inspections would benefit producers across the board. The Port of Garibaldi houses many independently owned seafood producers, few of which ship internationally.

The difficulty with forming this coalition is the fierce independence of many coastal fishers and producers. When exploring the potential for expanding markets, most producers shy away from the idea of uniting with other producers for fear of becoming part of one big conglomerate. However, in such a rapidly expanding market, if a producer is unable to compete, it will eventually get pushed out of the market.

Alternative Seafood Products

Since critical mass is such an issue for Oregon producers, supplementing the supply of Dungeness crab and Pacific oyster with alternative products is a good way to bolster sales volume and reduce shipping costs.

Sea cucumbers, geoducks, and hagfish are potential options. These are products that have no significant market in the U.S., which means that, unlike Dungeness crab, there is no domestic competition for the resource.

Recently, procedures for growing sea cucumbers have been developed and are part of the increased research on aquaculture being done in the U.S. The ability to grow this commodity allows for more consistency in the supply and control over its quality. Aquaculture also allows for year-round production, yielding a product to market during off-peak times for seasonal shellfish.

Another benefit of introducing these products is their durability during live shipment. Unlike Dungeness crabs, these animals can withstand long travel times in less than ideal conditions and still arrive to the consumer alive and healthy.

An important consideration is the fluctuation in demand for these types of products. In the Asian market seafood trends arise, and then quickly fade. For example, sea urchin was in demand in the last few years, but the market plummeted when consumers were no longer interested. Dungeness crab and oysters have a more consistent following, and more market research would need to be done to verify that the market is strong for these alternative items as well.

Outsource NOAA Inspections

The high cost of receiving health certificates is a huge barrier for many producers. Developing a method to reduce inspection costs could significantly improve industry participation and help expand the market.

Currently NOAA and Oregon Department of Agriculture (ODA) are working to create a cross-training program that would allow ODA employees to inspect and certify shellfish for export, but issue a NOAA certificate. This is a delicate process, as China is only willing to accept certificates issued by NOAA. If the certificates were issued through ODA, with no mention of NOAA, a shipment would most likely be rejected. Therefore, it is important to develop a process that acknowledges the role of both agencies and have it approved by importing countries. This would reduce costs, as ODA employees charge a lower hourly rate and are stationed in more locations throughout Oregon.

Another option is having more NOAA inspectors stationed throughout Oregon instead of having them travel from Seattle. If one or two NOAA employees were stationed along the coast or at the Portland Airport full-time, it would reduce travel time and allow for product to be inspected before packing. Ultimately this would help producers retain product quality and encourage shipment out of Oregon.

At present, the USDA allows for veterinarians to issue health certificates. NOAA could use the same model to develop an accreditation program to train veterinarians to issue health certificates for live seafood. This creates wide network of potential inspectors, creating a more timely and cost-effective way to conduct inspections.

As noted above, a potential problem is China’s unwillingness to accept certificates issued by non-NOAA inspectors, so special care must be taken to discuss this with Chinese government officials and customers to ensure full understanding of new inspection procedures. Furthermore, NOAA must be willing to relinquish some control over the Seafood Inspection Program in order for other government agencies and individuals to become legitimately integrated into the program.

Centralized Seafood Receiving Facility

The final suggestion for improving Oregon's international export industry is the culmination of the previous three suggestions.

The disjointed supply chain is a major impediment to exporting live seafood from Oregon to the Asian market. The lack of uniformity negatively impacts the quality and value of the live shellfish being shipped, which can negatively impact future transactions. A centralized receiving facility located at the Port of Portland would help integrate all the steps in getting product to market.

The Port of Portland has many vacant buildings to contain the centralized receiving facility. The Port has warehouse facilities, which would be perfect for containing this one-stop shop for international shipping. Producers could route refrigerated trucks and have their shipments inspected, packed, security cleared, and delivered to the carrier's cargo loading dock within a few hours of arriving at the airport.

A full-time NOAA inspector stationed at such a facility would ensure that all products coming in receive an inspection and health certificate, with ample time left for packing. The ability to inspect before packing allows the producer's original shipping container to remain intact and reduces handling of the product.

Since Customs clearance is done electronically, such a facility would allow officers to locate the shipment and rectify any mistakes in documentation.

Creating this facility would greatly benefit producers who struggle with the logistics of shipping their shellfish internationally, as well as those interested in breaking into the market. The Port of Portland would also benefit, as this could increase cargo traffic going through PDX and attract more potential exporters.

Funding will certainly be an issue, but with enough producer and industry support the government might see the economic benefit of such a project and enter into a partnership with industry to develop such a facility.

Some producers may still choose to ship out of Seattle to have more carrier options, or from Canada to avoid NOAA health inspections, but with enough incentives in place Portland could become a larger hub in exporting live seafood to Asia.

Oregon has the potential to benefit economically from the growing demand for live seafood in China and other Asian countries, but it has a number of barriers to address before it can fully exploit this potential market.

With the continued cooperation of Oregon's crab and oyster producers, government agencies, the legislature, and the Port or Portland, solutions will lead to the expansion of the industry.

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Appendix: Interviews

Betty Mujica, Oregon Sea Grant

The following individuals were interviewed by Betty Mujica (June 22, 2011–July 24, 2011):

- Liu Xin (Oregon Oyster Farms)
- Darus Peake (Tillamook Bay Boathouse)
- Dawn Smith (Food Safety Division, ODA)
- Jeff Feldner (Seafood & Fisheries Specialist, OSU Sea Grant Extension)
- Rick Aizawa (Port of Portland, Air Service Development Manager)
- Matt Hoffman and Annette Price (Port of Portland)
- Scott Goddin (Director, Portland U.S. Export Assistance Center)
- David Stocking (NOAA Consumer Safety Officer, Seafood Inspection Program)
- Bill Raine (Freight Forwarder, Express NW [Perishables]) and
- Mark Dempsey (Account Manager, FedEx Cargo)

Sea Grant Oregon

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