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The feasibility of crop insurance for saltwater aquaculture

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EXECUTIVE SUMMARY

A new industry

- While aquaculture has a long history, modern intensive aquaculture is quite recent. Some parts of modern aquaculture are built around species that only recently have been domesticated for farming in more intensive production systems. Moreover, unlike animal agriculture, aquaculture involves a much larger and diverse range of species, each with their own distinct character under domestication.

Fragile, sensitive animals

- Most species are highly sensitive to unfavorable aquatic environmental conditions. Minor deviations from optimal conditions can result in poor growth, poor health, and high mortality. Biosecurity measures must ensure that potential threats to the health and well-being of aquatic animals are addressed. Threats can be introduced through the water, purchased broodstock, eggs, fry, fingerlings, feed, or visiting vehicles and personnel.

A complex aquatic environment

- Aquatic environments contain dissolved compounds and various organisms that both promote and constrain aquatic animal health. Aquaculture management demands continuous monitoring of the aquatic environment to ensure the conditions are conducive to good health and growth. The volume and quality of the water supply available to the aquaculture facilities represents one of the key factors affecting success.

The structure of aquaculture

- Aquaculture produces a range of products. Food fish account for roughly 60% of sales of US aquaculture products (Census of Agriculture 2007). Sport fish account for 6% of sales, and baitfish 3%, ornamental fish 4%, crustaceans 4%, mollusks 17% and other aquaculture 6%.

Scope of insurance feasibility study

- Our attention focuses on a small list of saltwater aquatic animals that are raised for food (salmon, and shrimp). Atlantic salmon is the only species grown in any volume in saltwater aquaculture in the United States.
- Alaska invests heavily in Pacific salmon hatcheries and the release of juveniles to support ocean ranching of Pacific salmon species. These are excluded from the scope of this study. The breeding and production of disease-resistant young shrimp (nauplii and post-larvae (PL)) are also excluded.
- Hence, we review the feasibility of providing mortality insurance for the main saltwater species primarily farmed in the United States for use as food (salmon and marine shrimp). The US salmon and shrimp sectors differ considerably in terms of structure, relative scale, production methods, risk profiles and competitive position.
- We rejected at an early stage the provision of insurance for poor quality product. Problems with the appearance of the final product (including those resulting from diseases) are strongly

influenced by management practices. Because of this, offering coverage for the loss of value of aquaculture products through RMA insurance is inappropriate.

Absence of statistical description of the US aquaculture sector

- The last Census of Aquaculture was in 2005. The 2010 Census of Aquaculture was canceled. Some aspects of aquaculture production were covered in the 2007 Census of Agriculture, although the coverage was very limited. There have been many changes in the condition of the sector since the last Census of Aquaculture. While both the salmon and shrimp production sectors are relatively small, there is very little reliable data that describes farm performance and its relationship to production practices.

US aquaculture is under intensive and ongoing competitive pressure

- The US imports 85% of the seafood it consumes. In general, US aquaculture has been under substantial pressure because of competition from imports. Most of US aquaculture cannot compete in commodity markets where price is critical. Consequently, in general, there is emphasis on supplying markets where premium prices are available, and where imported supplies cannot compete (e.g. local and live markets).

- This is less true for the US salmon sector, which competes in the US market against imported fresh farmed supplies of Atlantic salmon, and some fresh and frozen ocean-harvested Pacific salmon mainly from Alaska. The US shrimp industry has contracted rapidly and is struggling for survival. There are ongoing attempts to develop inland saltwater shrimp production in recirculating aquaculture systems (RAS) to meet local market requirements. So far, this represents a very small volume of production.

- There are major constraints on the growth of the US saltwater aquaculture sector. In particular, the limited availability of suitable marine sites for cage production of salmon, the low level of competitiveness of US shrimp production against the competition, the regulatory framework affecting the use of coastal land and marine areas, and the lack of critical mass inhibit growth in the industry. Investments in inland recirculating systems are expensive and are largely targeted at meeting the needs of higher value niche markets.

US aquaculture output value is relatively small

- Salmon is estimated to be the second most important farmed species in the United States with a 2010 value of $150 million. This value varies considerably with the fluctuations in the annual average market price. The value of shrimp production is estimated to be less than $10 million, less than half of the figure recorded in the 2005 Census of Aquaculture. This represents a very small sector – only 9 of the 124 agriculture and horticultural crop categories identified in the Crop Values 2010 report issued by the National Agricultural Statistics Service (NASS), had a value of less than $10 million. There are several other species in saltwater aquaculture production in the United States but none have significant levels of production.

The structure of each industry varies considerably

- The ownership of the salmon industry is highly concentrated with only two international players operating all the farms off the coast of Maine and Washington. One of these is

Canadian with operations in Canada, Chile, southern Europe and the United States. The other is a US-based venture capital company with seafood and aquaculture interests in various countries.

- The shrimp industry (five players in Texas, accounting for 85% of US production) comprises a very small number of operations with different levels of intensity of production and hence very different risks. In addition, there are a small number (we estimate 5 or 6 at most) operating shrimp production in RAS. RAS shrimp production has witnessed several business failures as investors have failed to identify the potential risks of this relatively new method of shrimp culture.

Production systems with very different character

- Atlantic salmon are almost exclusively grown in saltwater net cages in protected, inshore marine environments, although there is one land-based company growing coho salmon in freshwater in the state of Washington, and there are plans for RAS production of Atlantic salmon in freshwater in the northeast. Shrimp are mainly cultured in pond systems, although the production system adopted may vary considerably depending on the stocking intensity. Traditionally, these ponds involved continuous recirculation of saltwater taken from adjacent estuarine or inshore marine sources. More recently, the exchange of water has been decreased substantially in response to environmental concerns. Pond systems tend to be much cheaper to operate, largely because of the lower investment costs required. Recirculating systems for inland shrimp are a recent innovation. They are the most expensive production system as they involve investment in facilities to raise aquatic animals in a more intensive environment. This involves investing in buildings and equipment that can both control and monitor the continuously recirculating aqueous environment of the shrimp and the resulting wastewater and waste material. Interest in recirculating systems has grown recently as there are fewer issues with wastewater and adverse environmental impacts, and they can produce warm water species throughout the year.

- There is substantial interest in offshore aquaculture production, although the development of this sector is embryonic. Various technologies have been developed to enhance the resilience of cages in offshore conditions and to reduce various direct costs (e.g. labor and transport). However, apart from the Mediterranean production of sea bass/sea bream, there has been little success in developing an offshore aquaculture industry. Regulatory factors remain a major constraint on offshore production in US state and federal waters, despite recent policy initiatives. There are a handful of commercial and experimental fish farming operations in state-controlled waters off of Hawaii, California and some states in the northeast. These are each involved in raising different species (but not salmon or shrimp).

Production systems have different types of risk

- With the exception of RAS, there are limited opportunities to control growing conditions in most production systems. Net cages are located in a marine environment that is vulnerable to change. The quality of the water can be modified by aeration or forced circulation, but control may be limited. Enhanced net cage systems suitable for offshore production reduce some of the challenges in relation to water quality, although new risks are likely to be present. Pond systems are more exposed to weather and other perils. The ability to closely monitor and adjust the water quality is more limited. Consequently, great care has to be taken to ensure that stocking densities and feed procedures do not result in changes in water quality that stress the stock. Predation is a challenge for both net cages and ponds as appropriate protection is expensive. Shrimp cultured in pond systems are vulnerable to diseases that may be transmitted by either incoming water supply or overflying birds. Shrimp production throughout the world has been plagued by occasional disease outbreaks that have decimated production.

- Net cages need careful location and regional or area management to ensure that farmable water is available during all seasons. Again, stocking densities and feeding routines are critical to maintaining fish health and avoiding environmental deterioration. Novel technologies such as underwater cameras and monitors are available to assist management control. Movement between facilities has been common, although, following requirements for certification of responsible management (e.g., for Global Aquaculture Alliance (GAA) Atlantic salmon management certification), there is a trend to more single batch production.

- Recirculating systems offer considerable opportunity to monitor and control the aquatic environment. However, the engineering and management challenge is probably greater than in any of the other systems as the system must continually maintain water quality by recirculation through filters and treatment. High levels of intensity result in narrow margins of error for a wide range of aqueous parameters, and very high levels of management expertise are required to ensure continuous high levels of performance. The design and engineering of recirculating systems is critical in minimizing the threat of bacterial and fungal diseases. Tight biosecurity measures are required to ensure that disease and pest challenges are minimized. The use of saltwater, with its corrosive properties, represents an additional challenge for engineering the production of shrimp in RAS. Also, raising shrimp in intensive recirculating systems is relatively novel and scientific understanding is poorly developed to support the industry. The US Marine Shrimp Program now focuses almost all of its attention on production technologies for RAS.

Perils

- A wide range of perils can cause mortality in fish, and these will vary by production system. As indicated above, many are linked to the quality of business management and aquatic animal husbandry. Biosecurity breaches that result in disease outbreaks are a major concern, although attention to detail can reduce this risk. In particular, both salmon and shrimp production has been seriously compromised by the introduction of disease through contaminated genetic or juvenile stock. Ensuring that eggs and young stock are disease free represents a critical component of biosecurity. Monitoring devices and alarm systems should be an integral part of all aquaculture facilities. All equipment should be maintained adequately for continuous operation, and for certain key pieces of equipment, backup is required. The fish farmer needs to have in stock appropriate resources to ensure that electricity can be generated in the event of a power outage. Reserve oxygen supplies, filters and other essential equipment should be in stock to ensure the regular functioning of pumps, lifts and filters.

- As a ready supply of good quality water is critical to aquaculture, any threat to its supply represents a major risk. Flooding and other weather related events are a peril associated with coastal aquaculture, particularly for pond-based systems. Any deterioration in the quality of water supply represents another peril. This can be caused by a wide range of factors. In saltwater aquaculture, human activity can pollute farmed water, although a number of natural events can also threaten water quality.

- There are no published data that describe the incidence of these perils in salmon or shrimp farming, nor the size of losses. However, the private insurance industry is likely to hold these data for the significant volume of insured farmed Atlantic salmon production globally. Disease is likely to be an most important cause of loss for both species.

Disease

- Viral diseases are by far the most important diseases having economic impact on salmon and shrimp production. The outbreak of the virus infectious salmon anemia (ISA) in Chile in 2007 resulted in a halving of production, the laying off of 26,000 workers, and estimated losses of $2 billion. The Maine salmon industry was decimated by an outbreak of the same disease in 2001, which was contained by compulsory depopulation and a government animal health emergency indemnity program that cost $8.3 million. Shrimp industries in several countries have been almost wiped out by similar viral disease events.

- Both salmon and shrimp are also subject to bacterial diseases and parasite threats. There are reports that shrimp produced in a RAS are subject to more bacterial and fungal challenges for unknown reasons, although stress is one likely explanation. Infection may result in death, lethargy, generally poor growth, or reduced marketability due to appearance. For most common diseases, there is a correlation between the quality of management and the susceptibility to disease. For viral diseases, the most effective method of control is through stocking juveniles that have been bred from stock that are resistant to these viral diseases and are tested as free of other diseases, although some vaccines have been developed to combat some viruses. Both the Atlantic salmon and marine shrimp industries rely heavily on the maintenance of general health through improved breeding, and disease free hatchery procedures and juvenile/post-larvae transfers to production containment structures. As with other species, disease outbreaks are often linked to high levels of stress in aquatic animals because of poor management of water quality, crowding, or inappropriate feed.

- Land-based aquaculture operations have available to them a number of procedures or treatments to modify the quality of water (e.g. aeration, filtering, UV treatment, etc.). In some cases, the only solution for serious viral or bacterial diseases is to depopulate ponds or net pens and disinfect or relocate a containment structure to remove or isolate the cause of the disease. In general, with both fixed and mobile containment structures, fallowing should be an integral part of a production plan to break a disease or parasite cycle. Fallowing of net cages is also recommended to ensure that waste does not accumulate on lake, reservoir, or marine floors. There are a limited number of animal health products that can be used to treat some diseases.

The earlier NRMFPA review of feasibility of crop insurance

- The National Risk Management Feasibility Program for Aquaculture (NRMFPA) study reviewed the crop insurance feasibility for catfish, trout, and baitfish in freshwater and salmon in saltwater. Baitfish and salmon were rejected as candidates. Baitfish were rejected because of lack of interest in the industry, sparse price data, and difficulties measuring inventory and loss. Salmon was rejected as private insurance is available to that sector and is regularly purchased. Catfish insurance was recommended as a pilot to cover disruption in electricity supply, and it excluded catastrophic coverage except flood and rupture of containment structures because of flood. Trout production in raceways was recommended as feasible, covering mortality losses because of some specified diseases and other general perils as part of catastrophic coverage.

- The previous study took place over seven years and included several specific scientific studies. The program involved collaboration among university aquaculture departments, extension workers, and representatives of the different species industries. While most of this research focused on trout and catfish production, a profile was prepared for salmon and several components of the research covered crop insurance issues that are relevant to all species. There was no consideration of marine shrimp (*litopenaeus vannamei*). For example, the review of issues such as inventory measurement, disease spread, private sector insurance and yield verification were of value when considering aquaculture insurance generally, as were the workshops with actuarial practitioners, aquaculture production specialists and farmers. None of the documents supplied to us for this project suggested that any actuarial analysis was undertaken for the salmon industry. Indeed, there is no reference to any specific analysis of the insurability of the US salmon industry in any of the documents. Apart from the salmon profile, the only specific reference to salmon insurability is made in a letter to salmon producers and a single paragraph in the project report. The RMA staff recommended against proceeding with draft policies prepared for trout and catfish, and this recommendation was endorsed by the Board of the FCIC.

Our approach

- Our feasibility study reviews that material, updates the information on Atlantic salmon, and provides a review of marine shrimp. It also focuses on some of the key issues identified in the previous study. Our approach is based on an assessment of the size and structure of the industry, insurability, determinability, measurability, actuarial assessment, and availability of private insurance.

The size and structure of the industry:

- Industry size and/or structure considerations raise challenges for RMA industry insurance plans for both salmon and shrimp. The salmon industry is of good size but is comprised of only two companies. The shrimp industry is very small, with only a few producers.

Insurability and determinability

Knowledge of the perils that might result in loss:

- It is relatively easy for specialists in the field to arrive at a list of perils that can affect production at different stages for both species reviewed. However, there is little empirical data on the incidence of those perils. In addition to losses because of natural (weather-related) events, disease and parasites appear to be the most important perils affecting shrimp and salmon production.

The perils must result in acute loss:

- In general, losses that result from poor growth are difficult to assess and attribute during the grow-out period. Poor growth can result from a wide range of factors, most of which can be influenced by the quality of management, or the quality of the fingerlings or post-larvae. Perils that result in acute losses and mortality are more appropriately included in crop insurance plans. Both shrimp and salmon are subject to diseases that can inflict acute loss and high levels of mortality.

The ease of determining the cause of loss:

- As in any crop insurance plan, issues can arise over the precise cause of loss. For example, disease may impact production because an electricity outage stopped pumps from operating for a short period, resulting in deterioration in water quality and greater susceptibility to disease. Many diseases can be identified relatively easily, although some will need investigation by a reputable specialized analytical laboratory. In general, the US is well equipped with expertise to identify the leading shrimp and salmon diseases. Both salmon and shrimp are widely cultivated globally and more is understood about their culture than most other farmed aquatic animals

The extent to which management affects the impact of perils and losses:

- While relatively small in international terms, the US salmon industry has the experience and capability to meet international standards of husbandry. In general, management can impact the incidence of a wide range of perils in salmon and shrimp, and in particular potential pest and disease risks. Good management practice will involve constant attention to the quality of the water medium in which fish or crustaceans are being grown. Poor management procedures can result in various disease issues, and constrain performance. The siting and physical configuration of an aquaculture operation influences the vulnerability to production risks such as disease. Sound organization and management requires investment in appropriate engineering and biosecurity measures to reduce the impact of perils and the potential for poor performance. In marine cage farming there is also the need to manage conditions within production areas or regions and for cooperation among neighboring farms.

- However, some diseases and water conditions are impossible to prevent. Operating in a marine environment reduces the control over the most critical production factor, the aqueous environment. Defining insurable perils in policies and underwriting documents represents a considerable challenge in aquaculture, especially where management actions play a key role, but even they may not be sufficient to prevent losses. The question that arises in the case of loss is 'Was enough done to prevent loss?' and 'can best management practice be defined to establish the limits of the marine finfish farmer's preventive actions'.

Measurability

The ease with which the size of the losses can be identified:

- Various alternative methods of measuring inventory are used within the industry. In commercial salmon production inventory is measured regularly based on the counting of stock added (usually based on counts on loading of smolts from nurseries), mortalities, and regular sampling of size of fish. In addition, feed use and anticipated growth rates can be used to confirm inventory levels. While inventory measures are never claimed to be highly accurate, these methods are regularly used in reporting inventory levels as part of private insurance plans. As yet, there are no technological advances to improve the level of accuracy in counting fish, sizing fish, or measuring biomass. The challenge of measuring inventory and losses is particularly difficult in pond systems as management control and monitoring is far more difficult. Measuring inventory of shrimp farms is particularly difficult and currently there are no methods that can be applied with accuracy. RAS production of shrimp offers a better opportunity to measure inventory as tanks are usually fairly small and mortalities are normally identifiable. In all cases, detailed monitoring and recording of mortalities is required. Inventory assessment for shrimp is a very serious constraint on the development of a workable industry crop insurance plan.

Actuarial assessment

The availability of price information:

- Publicly available and reasonably representative price information is available for salmon, and shrimp. However, in both these cases, there are no publicly quoted prices for domestic production, although proxies are available for those products that are sold into commodity markets. There are regular published farmed salmon and shrimp prices published for all leading import origins. Some shrimp producers (both pond and RAS) sell into local markets for which there are no regular price quotations.

Availability of production history:

- There are only very broad brush industry level data describing production. In the case of the salmon industry, this data is assembled by the states of Washington and Maine. There are no data that describe the production record of individual units. As there are only two companies involved, these data are commercially sensitive. Some data are assembled to describe the Texas shrimp industry and its five pond-based participants. However, these data do not reveal details of the different production systems in operation at each farm. The data collected on the shrimp farms are meaningless without this information. Other data suggest high pond performance variability and low survivability. Production history from shrimp raised in RAS systems is not available as this production system is relatively new and still at a developmental stage. No meaningful individual farm production history is available for salmon or shrimp to provide an indication of the variability in either production or mortality risk.

The availability of representative data that identify the performance of a species in a particular production system:

- The limited number of salmon operators restricts the availability of data. Proxy data for salmon are available from other major Atlantic salmon production areas (e.g. British Columbia), although there are important differences between pacific and Atlantic coast conditions. There are numerous reviews of salmon production in Norwegian fjords and in Scotland. There are some data available for shrimp from irregular academic studies although much of this is dated.

The availability of representative data that indicate likely costs of production and revenue from the aquaculture enterprise:

- There is poor availability of representative data on production costs and their variability by region or system. There are occasional academic studies that review these issues, but most are out of date. Most of these relate to production costs within a fairly narrow geographical boundary and are unlikely to be representative of national enterprise costs and revenues. In general, there is not the same intensity of study of aquaculture costs and revenues as might be found in crop agriculture.

The availability of data that indicate the incidence of perils that might result in loss:

- The data on the incidence of major perils are regularly assembled by the insurance industry to cover catastrophic insurance (e.g. flood, drought, hurricane, tornado, and storm). Salmon and shrimp production farms are highly concentrated geographically and hence identification of serious weather events should be straightforward. However, the availability of published data that describe the incidence of other perils in aquaculture is absent for salmon and shrimp. Serious notifiable diseases (such as Infectious salmon anemia (ISA) for salmon and white spot disease (WSSV) for shrimp) that have resulted in devastating losses are documented although few academic studies have reviewed the incidence of other diseases and their losses for these two aquaculture sectors in the US. We have collected some of this information in the summary profiles of these species. Disease and parasites (often interrelated) represent the most important perils facing all species and all production systems in salmon culture in net cages, although predation from sea mammals is a constant threat. Various parasites (such as sea lice - *Lepeophtheirus salmonis*) are a major issue for salmon aquaculture. These infestations can seriously affect product value and have led to major controversy over the impact of farmed salmon on wild populations. Some diseases are highly infectious and unless appropriate precautions are taken they can be quickly transmitted among different containment structures on the same operation. Low levels of dissolved oxygen can be serious in pond shrimp production, but there is no systematic description of incidence.

The availability of data on normal mortality:

- Estimates of normal mortality are available for salmon and shrimp from a number of academic and industry sources. The estimates for shrimp are highly variable and identifying an industry average for pond shrimp culture is very difficult. There are no supportable published data for shrimp in RAS, although anecdotal reports suggest these can be high. Most data refer only to the grow-out phase.

The extent to which risks of loss can be allocated to different stages of production:

- In general, stages of production can be identified, although there is little data that provides a representative view of the risks that impact production at these different stages. The production of eggs, fry, and smolts (the fingerling stage in salmon) and nauplii and post-larvae (the infant and juvenile stages of shrimp) involve the greatest losses of individuals. The grow-out period for salmon may also be represented by several different stages. As the stocking density of a net cage increases, fish of different sizes may need to be separated into other containment structures (although today in the US it is understood that the two farms are transitioning to a single class production system that does not involve movement between different production units). Mortality tends to be higher at the initial stages of grow-out when young fish and post-larvae are more vulnerable.

Other risk management provisions

Federal or state funded emergency programs:

- There have been several federal initiatives to assist agricultural producers as a result of disasters and all aquaculture producers can take advantage of the Non-insured Crop Disaster Assistance Program (NAP). We do not have access to data that will allow us to quantify the extent to which these programs are utilized. NAP provides catastrophic risk coverage of only 27.5% of the value of the crop, much less than would be provided by an RMA crop insurance program. While shrimp producers are eligible for NAP, we are unable to confirm whether offshore salmon farms can participate, although we suspect they can. APHIS has provided indemnities in the case of mandatory depopulation as a result of very infectious and serious diseases. This applied to an outbreak of infectious salmon anemia in Maine in 2001.

Availability of relevant futures markets:

- There is one salmon futures market operating in Norway in local currency. This has minor relevance to risk management in the Atlantic salmon industry in the United States. Shrimp producers have no facility to manage price risks.

Other farm enterprises:

- Both salmon operations are large commercial companies with international interests and have diversified their production risks horizontally (through geography) and vertically (through hatchery, feed and trading operations). Some pond shrimp operations are vertically integrated with hatchery, processing and trading operations. There is no data describing the extent to which aquaculture activities are shared with other farm activities.

The availability and use of private insurance:

- Private mortality insurance is only available for species that are farmed in volume and where there is understanding of production practices and production experience. This is limited to Norway, Chile, Scotland, and parts of the Mediterranean, and the species Atlantic salmon and seabass/bream. In the US, Atlantic salmon producers are able to purchase private insurance that covers mortality. We have no information on the use of private insurance among RAS shrimp producers, although we understand that shrimp production globally is not insured because of the very high costs of gaining coverage.

Other issues

The likely level of demand and willingness to pay appropriate premiums:

- We understand that the salmon industry is concerned at the cost of private insurance, Most of the international farmed salmon sector buys private insurance. A major stimulus has been the insistence on mortality insurance as a condition of financing. Although we have no evidence, industry observers suggest that under its current financial conditions, US shrimp farms would be highly unlikely to pay the premiums necessary to cover for mortality insurance. These premiums would be high in recognition of the many challenges that face the supply of crop insurance to shrimp farmers.

The risk of moral hazard:

- Because of the challenges in identifying the scale of loss, there is a high risk of moral hazard (particularly in the shrimp sector). Inventory assessments are extremely difficult to make and the insureds would need to maintain detailed records to confirm inventory at any point in the production cycle. Various mechanisms such as deductibles can reduce but not eliminate the risk of moral hazard. Practices such as movement of stock between containment structures or units of production, or delayed sales between calendar years complicate inventory reporting and measurement and raise moral hazard risk. The US salmon sector is well organized in terms of record keeping and familiar with insuring its stock. However, this is not the case for the shrimp industry where inventory measurement would be a serious challenge.

The risk of adverse selection:

- Because of the limited published data on the two sectors, it would be difficult to develop a rating structure that adequately reflects the diverse production risks. As a result, there is a risk of adverse selection should aquaculture insurance be offered (although the concept of adverse selection would appear redundant in the case of the US salmon industry with its two producers).

The ease of defining units of production:

- In the previous review of aquaculture feasibility, a unit was defined as 'all the insurable containment structures of (the farm raised species) in the county in which you have a share on the date coverage begins for the crop year". This definition may involve considerable challenges when aggregating data from many diverse containment structures under the operation of one company within one county. This particularly applies to shrimp. This definition might need reconsideration in the case of marine net cage production of salmon as the definition of county boundaries in coastal locations might be questioned.

The availability of insurance industry expertise and resources to support an RMA plan for a specific species and production system:

- In general, the expertise of offering and supporting aquaculture insurance products within the United States is extremely limited. The market is relatively small, the data availability on the incidence and impact of perils is incomplete, and the costs of developing and supporting products and carrying out loss adjustment procedures are significant. This represents a major constraint on the feasibility of supplying RMA aquaculture crop insurance products. NAP has experience of administering catastrophic coverage. We understand that loss assessment represents a major challenge for that program, although we are unable to quantify NAP use in the industry. However, a very small number of local loss adjusters would be required for both salmon and shrimp as the industries are relatively small and regionally compact.

Our overall conclusion and recommendation

An acceptable risk exists when:

- an actuarially sound premium rate can be determined and charged to customers who are willing to pay the price;
- customers cannot adversely select against the program;
- moral hazards are avoidable and controllable;
- there is enough interest for the risk to be spread over an acceptable number of insureds and geographic areas;

- effective loss controls are available; and
- perils are identified.

While the shrimp and salmon sectors faces many perils, several critical factors argue against RMA developing industry plans. These are listed below.

- The highly concentrated ownership of the **salmon** and **shrimp** sectors is inappropriate for an industry crop insurance plan. This restricts the spreading of risk over a sufficient number of insureds.
- The **salmon** industry is supplied by a well-established international private insurance sector.
- The small industry size of the **shrimp** sector suggests that there will be little incentive for AIPs to participate in the program.
- There are severe potential moral hazard and adverse selection challenges because of the high importance of good management practice in reducing the incidence of perils in **all species and systems**. This challenge is substantial in the case of **shrimp** production, and small in the case of **salmon**.
- The highly diverse recirculating systems used in RAS shrimp production and the absence of sound statistical description of the character and experience of these systems poses serious challenges in actuarial analysis. These have widely varying degrees of effectiveness in controlling disease and mortality. Thus, any rating system would need to include type of RAS as a rating variable, but we do not have data that would allow it to be quantified.
- The challenge of measuring inventory and losses in **shrimp pond production systems** threatens the integrity of a crop insurance plan. Measurement of inventory is challenged by the absence of accurate biomass assessment or counting methods. Also, the lack of clear evidence of mortalities and cannibalism because of uneven stocking sizes or poor feeding, may frustrate accurate inventory measurement.
- Measurement systems that can be applied with some confidence are available for **salmon** in **net cages**. However, even these are challenged by multiyear production and the occasional practice of regularly moving **salmon** between different cages and units to maximize efficient carrying capacity.
- The studies reviewed and data collected suggest that the risk of loss in **pond shrimp** production in the US is very high. The lack of critical data (e.g. on prices (for US grown shrimp), causes of mortality, harvests, yields, losses, etc.) frustrates solid actuarial analysis and necessitates rates that could be higher than rates reflective of the true risk. This is likely to reduce **shrimp** industry participation.
- The lack of adequate data for sound actuarial analysis for **all species** could also lead to problems of adverse selection.
- There is little evidence to assist conclusions on willingness to pay, although we suspect that the shrimp industry in its current economic plight is unlikely to be a source of enthusiastic customers for policies with actuarially responsible rates.

- The cost of AIPs acquiring the necessary experience and skills to implement and administer these programs would be high and their interest in participation is likely to be very low.

The NRMFPA report concluded:

"*Based on the research and the application of the insurability criteria, the program will recommend to RMA that no further development of insurance programs for the US farmed salmon industry takes place at this time.*"

The reasons for this recommendation include:

- the availability of insurance from the private sector (one of the RMA's basic tenets is not to offer competing insurance products to markets already being served by the private sector);
- The small number of insurable units; and the absence of a farm level market price data (while propriety price data can be obtained, these data may not reflect the actual market faced by farm salmon producers).

Based on the above, we conclude that insurance plans meeting FCIC standards are not feasible and we recommend that the RMA does not pursue an industry crop insurance plan for either of the species we have reviewed.

SECTION 1: THE FEASIBILITY REVIEW

1.1 Background

The Food, Conservation, and Energy Act of 2008 requires RMA to enter into contracts to carry out research and development regarding a policy to insure the production of aquaculture species in aquaculture operations. This contract covers research of the potential to develop an insurance product for aquaculture that is either: (i) based on market prices and yields; or (ii) incorporated into existing policies covering adjusted gross revenue; and (iii) provides protection for production or revenue losses, or both.

1.2 Objectives

The objective of this contract is to obtain and analyze data to determine the feasibility of insuring freshwater aquaculture in the species listed below. This report will explain the issues associated with operating an aquaculture insurance program and assess the likelihood of successfully developing such a program. If any of the species do prove to be viable candidates for aquaculture insurance then a type of insurance plan will be recommended.

1.3 Scope of study

1.3.1 Species

The scope of the research extends to addressing the insurance of saltwater species, including but not limited to (i) Atlantic Salmon (*salmo salar*); and (ii) Shrimp (*Penaeus* now classified as *Litopenaeus vannamei*). The common name of the latter is whiteleg shrimp. The US does not produce the other leading penaeus species, the giant tiger prawn (*Penaeus monodon).*

Our research revealed that while there are several other saltwater species in production; none were on a scale that warranted further detailed investigation (see section 5.1).

This report covers the saltwater species designated by Congress. However, the aquaculture methods used are very broadly similar between fresh and saltwater environments. Therefore, regardless of whether the water is fresh or salt, the RMA face many of the same issues and obstacles in the creation of aquaculture insurance.

1.3.2 Types of aquaculture production reviewed

We have considered the production system of each of the species from hatcheries to final harvesting. This often involves several distinct stages such as breeding and the production of the eggs, the raising of fry and fingerlings, and the grow-out stage which involves taking the fingerling to marketable size. This latter stage can be broken into different stages, often involving the transfer of the fish from one containment structure to another (and in some cases from one fish farming facility to another).

We have excluded consideration of salmon aquaculture for wild stock enhancement. This is heavily supported by state authorities that invest in hatcheries and egg and fingerling production facilities to maintain ocean populations.

We exclude from consideration hatcheries, largely because of their relatively small number and their heterogeneity (See discussion in section 4.3.1). In some native species, such as trout and the Pacific salmon species, some hatcheries have a major focus on stock enhancement. Consequently, the non-market factors mentioned above interfere with pricing and valuation of production.

1.4 Feasibility study approach

In planning this contract, we were aware that the RMA had participated in the National Risk Management Feasibility Program for Aquaculture (NRMFPA), which had extended over seven years and involved many aquaculture research institutions and researchers. That study had reviewed much of the information on markets, production systems, and data for four major aquaculture sectors in United States. Indeed, the results of the NRMFPA were presented to a meeting of the Board of Directors of the Federal Crop Insurance Corporation (FCIC) as recently as March 12, 2009.

We noted that RMA staff informed the Board of Directors that RMA was withdrawing the programs from consideration in the light of issues raised by expert reviewers, but would continue to build upon the research.

While much of the technical research undertaken as part of the NRMFPA remains valid, the market and economic context for the development of US aquaculture has changed greatly since its initiation. The sector has suffered considerably from competition from imports, although some remain optimistic about longer-term opportunities as the market environment changes and understanding of key technical and scientific underpinnings of aquatic animals and aquaculture production systems develop. In particular, there is growing understanding of the opportunities for land-based recirculating aquaculture systems (RAS), and there is growing attention devoted to offshore marine aquaculture. However, both of these face considerable constraints and it is highly unlikely that production from these sources will significantly change the current high level of dependence on imported supplies to meet US consumer requirements.

However, our contract required us to revisit salmon that had been considered as part of the NRMFPA.

Our work program has included the following components.

- A review of the documentation from the NRMFPA (see next sub-section).
- A review of the market and economic context of US aquaculture. This is critical as the structure of the US aquaculture sector has changed quite considerably in recent years because of pressures from competing sources in third world countries.
- An updated review of the previous species profiles (salmon). This reviews was prepared by the expert (John Forster) that participated in the preparation of the original species profiles for the NRMFPA.

- The development of summary species profiles for shrimp. These were prepared by Promar in consultation with our Subject Matter Experts (SMEs).
- A review of available data on species sector structure, production, location, and prices. We have sought an indication of the size distribution, the specialization in aquaculture as a source of revenue, the recent distribution, the leading players, and the systems of production in operation. As part of this stage we have reviewed the availability of data on aquaculture performance (yields, feed conversion rates, etc.) and prices. Our search for these data is restricted to either comprehensive cross-sectional data such as that collected by the large survey undertaken as part of NRMFPA, or of data from reliable sources extending over at least 10 years. The availability of reliable data on the US aquaculture sector is very limited.
- Descriptions of different production systems with a focus on RAS. RAS systems were not included in the previous review, and they have become relatively more important and attracted media attention and optimism. Again, this was developed in consultation with our SMEs. The species covered in this report are farmed in net cages, ponds, and RAS. Much of this will be summarized in the species profiles. The species information includes coverage of the following:
  - Economic importance (domestically and globally);
  - Adaptations;
  - Stages of growth;
  - Biological classification;
  - Important characteristics;
  - Rotational requirements;
  - Habitat requirements;
  - Predators;
  - Diseases;
  - Marketing; and
  - Water quality.
- Identification of key perils for each species.
- Update of the NRMFPA review of aquaculture insurance and its status.
- Discussion of the key insurance issues:
  - Measurement of inventory and loss because of covert perils;
  - Perils;
  - Cause of loss;
  - Determinability of cause of loss;

- Rating and pricing with little data;
- Other issues identified in the SOW - coverage by other government programs, coverage by RMA policies, etc.;
- Potential interest among insurance providers, aquaculture producers and leaders representing aquaculture producers;
- Willingness to pay for insurance to manage risks associated with aquaculture;
- Percentage of the total revenue that is attributed to each separate aquaculture operation;
- Prices; and,
- Other options for producers (i.e. private insurance, other state and federal programs).

- A review of pricing and rating issues.
- A risk analysis (as part of the species reviews).
- Consideration of feasibility and potential risk management plan design.

1.5 The review of documentation in the NRMFPA

Many of these issues were reviewed in the National Risk Management Feasibility Program for Aquaculture. This program was designed to be a partnership between RMA and Mississippi State University, beginning in 2000. The partnership lasted for seven years. This program was to help generate information for RMA to assess the feasibility of developing aquaculture crop insurance related to catfish, Atlantic salmon, trout and baitfish; the four most prominent species at the time. The scope of that project included:

- conducting feasibility studies on four species (catfish, trout, Atlantic salmon, baitfish - the latter a mixture of species);
- conducting listening sessions to gauge interest;
- collecting data regarding the risks associated with aquaculture production;
- determining if there is enough data to develop an insurance program;
- collecting or designing data needed for insurance product development;
- assessing the potential of various risk management tools and insurance designs; and,
- providing a feasibility report on the viability of alternative risk management designs.

We reviewed the NRMFPA documentation, the papers prepared for the Board of Directors of the FCIC, and the reviews of the feasibility study and draft policy documents by external reviewers. These are itemized below. Although much of this documentation covers species that are not covered in this report, many of the issues addressed are pertinent.

(a) Research documentation on the NRMFPA: This included the final report on the feasibility of ensuring farm raised catfish, Atlantic salmon, trout, and baitfish and its numerous appendices. These appendices included:

- profiles of the different species sectors (Appendices A, C, D)[1],
- notes of listening sessions, presentations and communications to industry representatives (Appendices E, G, H, Z, AA, EE),
- notes of workshops on risk management in aquaculture and actuarial analysis (Appendices V, W, X),
  - research reports that explored the verification of catfish, trout and baitfish yields and production (Appendices I, J),
  - a comprehensive survey of aquaculture insurance and practices (Appendix K),
  - research papers on actuarial analysis of scarce data (Appendix L),
  - novel methods to enumerate mortality in pond production (Appendix M),
  - a survey of catfish, trout, and baitfish producers (Appendices N, O, S, T, U),
  - concept papers relating to aquaculture and livestock disease insurance (Appendices BB, CC),
  - analysis of insurability of perils (Appendix FF),
  - sample insurance policies and supplementary documentation (Appendices GG, HH, II, JJ, KK),
  - sources of data (Appendix LL),
  - loss enumeration methods (Appendix MM),
  - actuarial analysis (Appendix NN), and
  - research on demand for insurance and potential market size (Appendices OO, PP).

(b) A detailed review of the package delivered to the Board of Directors of the FCIC relating to draft policies for farm raised catfish in ponds and trout in raceways. This included some of the documents mentioned above, but further documentation of:

- rating methodology (Part C)
- actuarial certification (Part D)
- pricing methodology (Part E)
- underwriting guides for catfish and trout (Part F)
- draft policy provisions (Part G)

[1] These references are to appendices in the unpublished NRMFPA insurability report supplied to us by RMA. For this report, we did not review in detail the appendices associated with baitfish.

- draft loss adjustment manuals (Part H) and
- draft amendments to RMA records (Part I).

(c) A detailed review of the expert assessments of the package delivered to the Board of Directors by five invited reviewers. Three focused on concepts and implementation of the policies and two on the actuarial analysis and rating and pricing.

1.6 Interviews and specialist support

Interviews and discussions were undertaken with a wide range of subject matter experts. In particular, assistance throughout the study on salmon, other marine finfish, and aquaculture systems was provided by John Forster, Port Angeles, WA. Granvil Treece, Aquaculture Specialist, Texas Sea Grant College Program, (Aquaculture systems) provided detailed information on the marine shrimp sector.

SECTION 2: US AQUACULTURE SECTOR CONTEXT

2.1 Global aquaculture development

The supply of seafood from capture fisheries has been severely limited by international efforts to sustain the populations of marine species. The marine environment has been overexploited and many species populations have been under considerable pressure. However, the demand for seafood is increasing rapidly, driven by demographics and increases in incomes prompting higher levels of consumption of animal protein. Capture fisheries are unable to increase their output, largely because of the pressure of overfishing and the various measures to manage populations. Thus, in recent years, the growth in the demand for seafood has been met almost entirely by the growth of aquaculture. As demand is anticipated to increase, only aquaculture can supply product to meet this demand. As a result, much is expected of aquaculture, and consequently the global aquaculture industry retains substantial levels of confidence for the future.

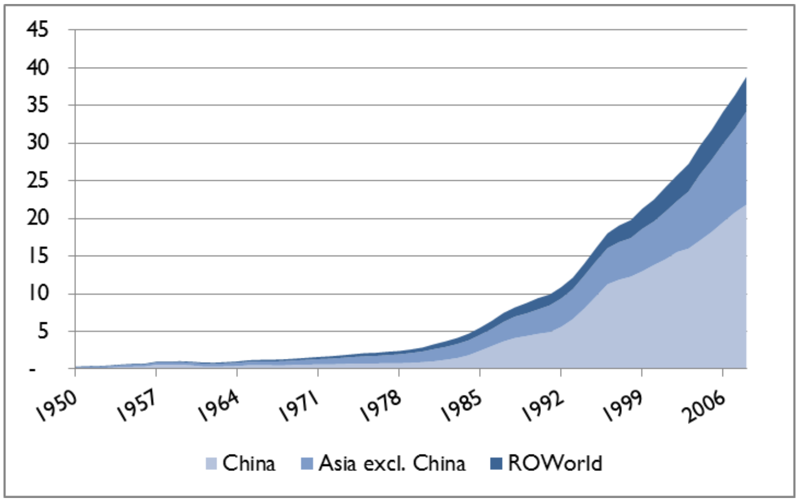
However, the growth of aquaculture production has been concentrated in a relatively small number of countries. Norway, Scotland, and Chile have been the focus of development of inshore marine aquaculture, producing mainly Atlantic salmon. Production has increased steadily in each of these regions as productivity has improved to reduce costs. However, the Chilean industry recently suffered severe losses from infectious salmon anemia (ISA), a virulent viral disease and is currently in the process of recovery. More recently, aquaculture has expanded rapidly in East Asia and Southeast Asia. Several countries have increased production very rapidly in response to strong demand for aquaculture products in North America, Japan and the European Union. China, Vietnam, Indonesia, Thailand, and Taiwan represent the bulk of aquaculture supplies to meet global needs. China and Asia have grown to be dominating forces (see Figure 1). In 2008, the latest global data available from FAO, China produced 56% of all finfish and crustacean, and Asia produced 88% (Table 1).

Table 1: Finfish and crustacean production, 2008

	million mt	Percent
China	21.8	56%
Rest of Asia	12.4	32%
Rest of World	4.6	12%
Total	38.8	100%

Source: FAO Fisheries and Aquaculture Department Statistics

Figure 1: The fish and crustacean production (million MT)

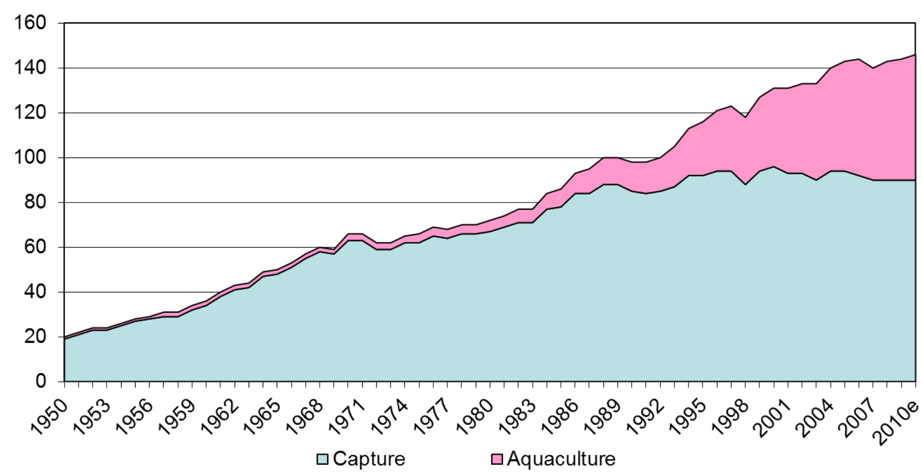


Source: FAO Fisheries and Aquaculture Department Statistics

2.1.1 Global production

Capture fisheries and all aquaculture production are shown in Figure 2. It will be seen that total production is growing, although that growth is generated by aquaculture. The output from capture fisheries has leveled off in recent years.

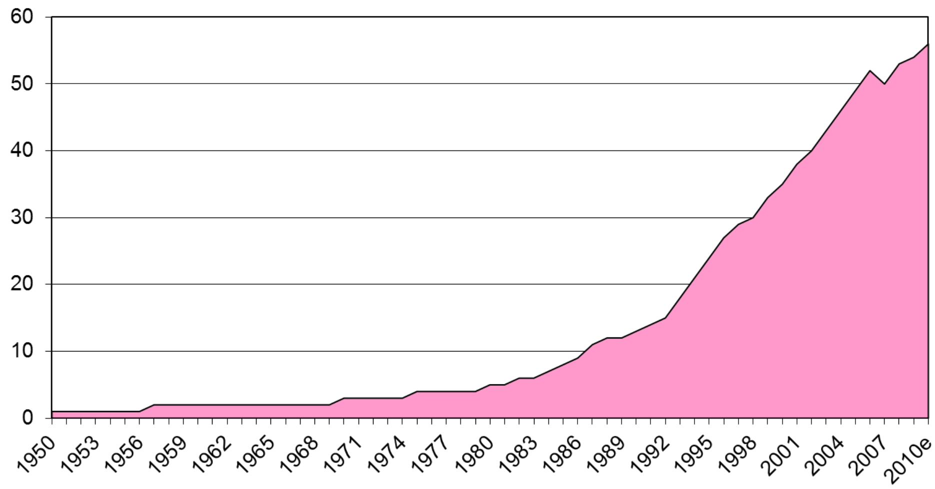
Figure 2: Development of capture and all aquaculture output (million MT)



Source: FAO aquaculture database

The growth rate of aquaculture is more clearly illustrated in Figure 3.

Figure 3: Development of aquaculture output (million MT)

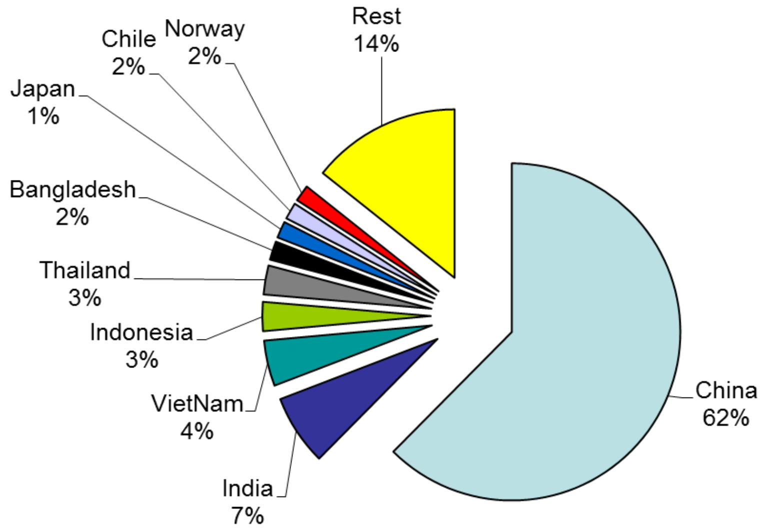


e = provisional
Source: FAO FishStat aquaculture database

As roughly 20% of capture fisheries output is used for feed or other non-food uses, the United Nation's Food and Agriculture Organization's (FAO) data and estimates suggest that farmed seafood now represents roughly one half of global human seafood consumption. The growth of aquaculture's share and the corresponding decline in the share of capture fisheries continues to change the face of the seafood value chain. In 1970, farmed fish accounted for only five percent of global seafood supply.

Asian countries dominate production (see Figure 4). The fastest growth has taken place in China, and that country is estimated to represent more than 60% of total farmed production today (including mollusks). Vietnam, Thailand, Indonesia and other East and Southeast Asian countries also figure prominently in global production. The United States is a minor player in global aquaculture. Its aquaculture accounts for an estimated 5 percent of its seafood supply. The changes worldwide have been driven by economics, demographics, and the increasing demand for food.

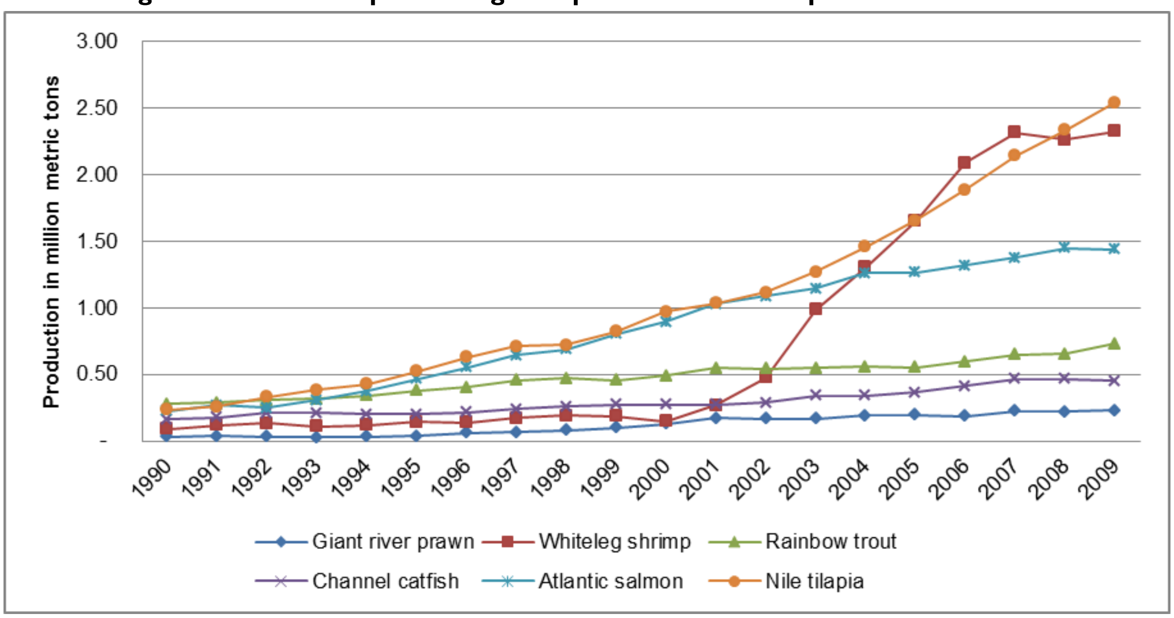
Figure 4: Share of aquaculture production, 2008



Source: FAO aquaculture database

The growth in aquaculture production of the freshwater and saltwater species under review is shown in Figure 5. The main US-farmed freshwater species are included for comparative purposes. It will be noted that global production of tilapia and whiteleg shrimp (*Litopenaeus vannamei*) has grown most rapidly.

Figure 5: The development of global production of the species under review



Source: FAO Fisheries and Aquaculture Department Statistics

2.1.2 US production

US production of the species we are reviewing is illustrated in Table 2. The main US-farmed freshwater species (catfish, trout, tilapia, hybrid striped bass and freshwater prawns) are included for comparative purposes.

Table 2: US aquaculture production volume and value, by species in 2005 and 2010

	2005		2010	
	million pounds	value in $m	million pounds	value in $m
Catfish (food-size)	450 [a] 607 [d]	429 [b]	376 [a/b]	402 [a/b]
Trout (food-size)*	60 [b]	63 [b]	45 [b]	63 [b]
Tilapia	17 [d]	29 [d]	22 [h]	55 [j]
Hybrid striped bass (food-size)	17 [d]	29 [d]		
	12 [e]	28 [e]	8 [e]	30 [e]
Largemouth bass (food-size)	4.2 [d]	8.3 [d]	n.a.	n.a.
Freshwater prawns (food-size)**	0.5 [d]	2.7 [d]	0.44 [g]	2.4 [g]
Salmon (food-size)	20.7 [d]	37 [d]	45.5 [f]	150 [j]
Shrimp (food-size)	8 [d]	18.6 [d]	3 [i]	7.2 [j]

Sources:

a. Hanson (2009 US catfish database)
b. NASS (Catfish and trout production annual reports)
c. Estimate based on Hanson (2009)
d. Census of Aquaculture 2005, NASS
e. Striped Bass Growers Association, 2011
f. Interviews with Maine and Washington State aquaculture specialists.
g. FAO- Fishstat, 2008
h. Personal Communication with NASS
i. Texas Aquaculture Association
j. Promar estimates are based on a price of $2.50 per pound. This figure has fluctuated greatly in the last two years.
k. Promar estimates based on an average price of salmon of $3.25/lb in 2010 (wholesale prices for whole fish have ranged from $1.2 to $3.85/lb over the last five years) and hence values fluctuate.

* Trout data from 2007 and 2010

** Freshwater prawns data from 2005 and 2008

2.1.3 Consumption

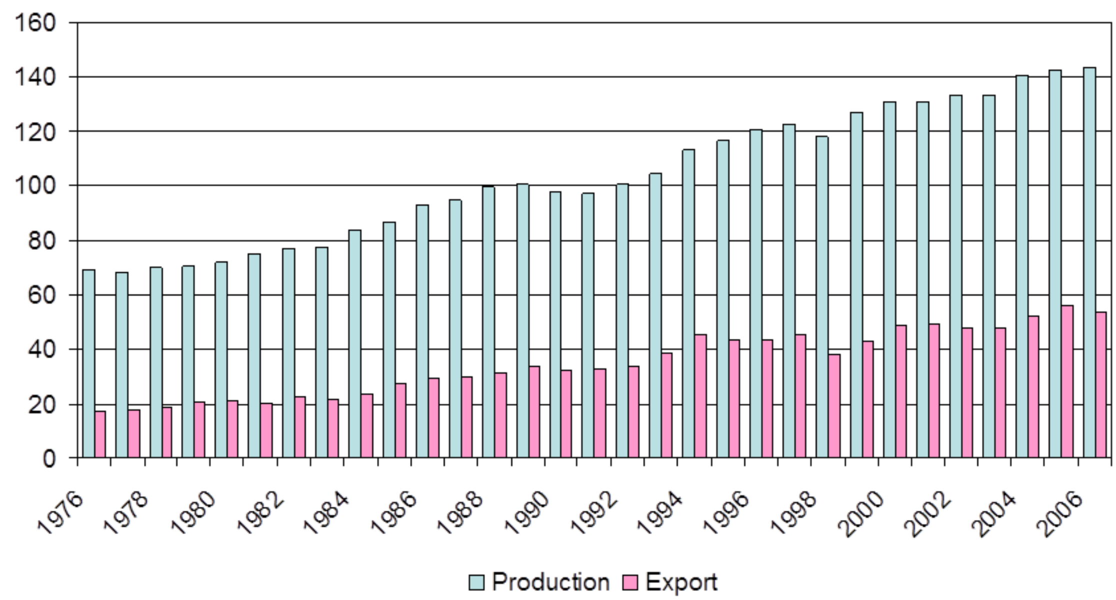
Today global per capita supply of food fish is estimated by FAO to be about 17 kg per annum in liveweight equivalents (13.7 kg if China is excluded) and rising slowly, up from 16 kg per annum in 1999.

Even as the amount of fish consumed continued to rise, it still represents a very small share of total animal protein consumed in regions of the world such as Oceania, Europe and North America. When measured in terms of the intake of animal protein FAO estimates it varies from 6.2 grams per capita per day in Oceania, 6.0 in Europe, 4.9 in Asia, 4.4 in North America to 2.4 in Africa. On average, in 2007 fish accounted for 16% of the global population's intake of animal proteins and 6% of all proteins consumed.

2.1.4 Global trade

The integration of global markets has allowed those regions with comparative advantage to expand their exports and become major suppliers in a global marketplace. As a result global trade in seafood is increasing rapidly. Exports are becoming a more important share of total production as shown in Figure 6.

Figure 6: Share of world fisheries production destined to exports

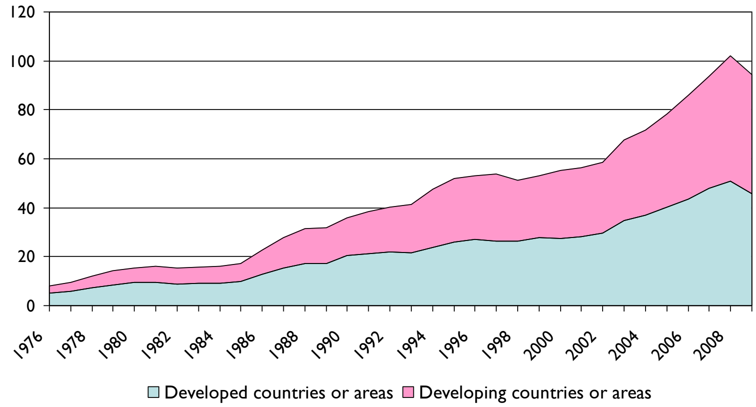


Source: FAO Fisheries and Aquaculture Department Statistics

Developing country exports now account for half of the global trade with a very large part of this originating in Asian countries. The largest exporter is now China, displacing Norway and Thailand from the top spot. China is a major location of reprocessing – importing capture supplies from other origins for reprocessing and re-export. The rising role of Vietnam in export trade is an important feature with most of its supplies originating in aquaculture. In contrast, exports from Taiwan are decreasing as its costs have increased. Some developed countries continue to play a major role in export markets with Norway, the US (mainly Alaska), and Canada being prominent (see Figure 7).

The largest exporters of aquaculture products are China, Norway (mainly salmon), Thailand, and Vietnam. Chile is also an important exporter although it recently suffered serious setbacks as a result of disease in its salmon farms.

Figure 7: World fish trade: Export value ($ billion)



Source: FAO Fisheries and Aquaculture Department Statistics

The main fish importers are Japan, the United States and the EU member states. Total global imports are estimated at roughly $100 - $110 billion, with these three accounting for almost 75% of all imports (66% if the EU is considered one trading bloc and intra-EU exports are ignored). The US and EU markets are both growing as more consumers seek alternatives to meat at the center of their plate, while the search for more diverse foods leads to longer term decline in Japan, a country that has a traditionally very high level of seafood consumption. Countries such as the US now rely on imported product for almost 85% of their consumption as the limited domestic supplies have found it difficult to compete with aquaculture-based systems (e.g. salmon from Norway, Scotland and Chile, and various white fish and shrimp from East and Southeast Asia).

2.1.5 Key factors affecting demand in mature markets

Large, influential buyers and the implications for suppliers

A critical factor influencing the nature of demand has been the growing importance and influence of large, retail food chains. They need continuity in supply, convenience-based service, and flexibility to supply what they need, and when and where they need it. They articulate consumer demand, often moving ahead of consumers in identifying products that meet emerging consumer points of value.

In some mature markets chain retailers have led the way in demanding responsible fisheries and aquaculture management and other features of the production and distribution process that differentiate them from others. The focus on how food is produced has been intense in the EU for some time, but it is becoming more important in North America and is very slowly gaining a hold in Japan. Hence it has become more important for suppliers to use sustainable and responsible management methods. Also, suppliers must deliver food that meets all food safety requirements and this increasingly includes traceability to point of production and its inputs.

The growing concentration of ownership of retail chains and their demands on their suppliers have major implications for those seeking to make headway at retail in mature markets. But similar changes are also occurring in developing countries as incomes and urbanization increase and more sophisticated technology can be purchased to improve the efficiency of the value chain from production to consumption.

The needs of the major retailers can only be met by those suppliers that can guarantee continuity, standardized quality specifications, the necessary certifications for food safety, responsible management and traceability, and lower competitive costs. This has focused attention on driving efficiencies into the entire production and distribution process through reaping economies of scale and investing in appropriate technologies. This search for competitive costs has promoted a major investment in reprocessing facilities in low labor cost countries where labor intensive filleting and product preparation activities can reduce costs (e.g. in China, Thailand, and Vietnam for reprocessing).

One impact of these changes at retail is increased concentration of ownership in the production, processing, and distribution sector for several keystone species (for example, farmed salmon, Mediterranean bass/bream, tilapia, and shrimp). Only large-scale operations can raise the capital necessary to invest in supplying all the necessary volume, quality and service requirements for the major species.

Branding has become a critical component to marketing some seafood products. While some markets have become extremely commoditized with all the emphasis on price, others are more sensitive to differentiation. Success in the Atlantic salmon industry depends on being price competitive. Some newer, smaller, more specialized markets may offer greater opportunity to differentiate products and develop a successful market position. However, product differentiation with branding is an expensive operation, especially as many retail chains seek brand support before they will consider placing the product on their shelves. This also favors those with deep pockets.

Seafood has faced many marketing challenges. It is challenging to handle in distribution, costs are high, and margins are reported to be lower than for many animal protein products. However, aquaculture has been easier to accommodate in large scale retail systems than wild product. Aquaculture products that are more standardized can be provided more continuously and predictably, and traceability is more straightforward. As a result it is easier to develop regular commercial relationships with major buyers or their suppliers. Also, aquaculture has been winning the battle over costs, and this is one important reason why it has expanded rapidly to bite into the capture fisheries' share of the market. To some extent major markets rely on aquaculture production in developing countries, where costs are generally lower (e.g. especially Asia, and South and Central America).

There are of course other smaller, more niche markets for higher value and more specialized products in some retail and food service outlets. These tend to be serviced by dedicated specialist distributors and represent the most attractive outlet for fresh product. Apart from upscale retailers, the major retail chains often do not have the expertise to handle genuine fresh product. They prefer refreshed product from frozen that can be more easily handled with a relatively low-skill labor force. Thus, prospects for success of higher value seafood products rests with this small, niche market, in retail, plus higher end or specialized food service outlets.

2.1.6 Asia dominates sub-tropical and tropical aquaculture production

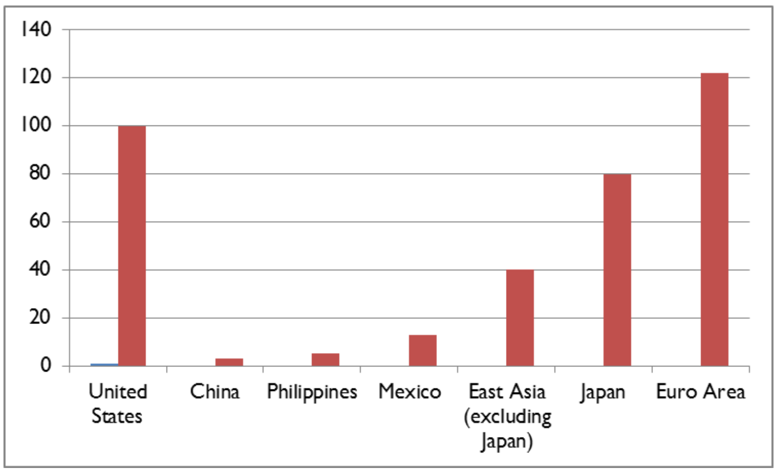
Salmon and shrimp are highly competitive commodity markets. Salmon and trout are also global commodities (particularly salmon) with Norway, Scotland, and Chile leading aquaculture production of Atlantic salmon and Chile leading production of rainbow trout. Each of these countries have developed substantial export-oriented sectors. The leading whiteleg shrimp producers are China, Thailand, and

Indonesia, with 47%, 22%, and 9%, respectively. Vietnam is also a major producer, but of the larger *monodon* species. .

There are several points to make.

- Asian aquaculture production generally benefits from substantially lower costs than those found in the United States. There are no reliable and standardized data available on production and processing costs and hence the sources of information are only anecdotal.
- Labor costs are lower in Asia and while this influences cost at all stages, it is particularly beneficial in respect to more labor intensive activities, and particularly those related to processing. The data below are for 2006 and some of these Asian advantages have been reduced.

Figure 8: Hourly compensation costs of manufacturing employees in selected economies and regions (Index $29.98 =100, 2006)



Source: US Department of Labor

- Feed costs usually make up the largest share of variable costs. These vary in importance depending on local resources. Several Asian suppliers have access to competitively priced feed, despite their distance from some key grain and oilseed suppliers. Indeed, most leading Asian suppliers now have access to leading aquafeed formulations as a result of investment by leading suppliers drawn by the volume of potential business and the concentration of aquaculture activity.
- Energy costs are likely to vary by country depending on energy policies and resources. Most are buying from fungible supplies that reflect world prices. In general, these are unlikely to vary significantly from costs in the United States.
- The cost of good quality fingerling fish, and naupliis and post-larvae (PL) for crustaceans is a key component in the costs of production and this will vary depending on species. For shrimp, the US has available ample supplies of good quality PLs, indeed, US researchers have played an important role in advancing shrimp genetics). Major players have made investments

to breed improved strains and to develop their own hatcheries to maintain high levels of biosecurity.

- Some leading farmed salmon production countries (Norway, Scotland, and Chile) have benefited from the advantages of scale and geographical concentration in the salmon sector, and similar regional concentrations have been key characteristics in the shrimp sector in Southeast Asia. These sectors have invested in the latest technologies to advance performance reduce prices, and compete strongly.
- Some producers with high labor costs (e.g., European producers of Atlantic salmon) have invested heavily in mechanization to maintain competitiveness.

2.2 The future

Consumption growth: In general, consumption will continue to grow as populations rise, and there will be a small increase in annual consumption per head. The FAO projects that an additional 40 million metric tons of seafood will be required by 2030 to add to their estimates of the 120 million metric tons consumed today. The captured supplies are unlikely to rise as harvest controls will continue to be in place to reduce over-exploitation of wild stocks. However, the production of an additional 40 million metric tons from aquaculture remains a major, and some think overoptimistic, challenge.

Environmental concerns: There are many issues that could affect the rate of growth. It is likely that environmental pressures will grow, although there is considerable evidence to suggest that producers will respond and will take these factors into consideration. Already many leading suppliers in Asia have attained or seek responsible management certification to ensure confirmation of broad economic, social, and environmental outcomes.

Eco-labeling: Many eco-labels are in use, and while the spawning of new labels confuses consumers, the pressure to manage aquaculture responsibly will become greater. There are active programs to give more prominence to certification and much of this effort has been led by the FAO with its draft guidelines for an ecosystem approach to aquaculture and aquaculture certification.

Regulatory constraints: Because of the potential use and environmental conflicts, aquaculture development is subject to many regulations. Certainly identifying suitable inland locations will become more challenging as populations grow and good quality water becomes more difficult to find or more expensive to use. Offshore aquaculture has suffered from lack of clarity of the rights to use offshore water columns. While it is likely that these issues will be resolved in countries with a more highly developed legal structure, other countries will present greater hurdles to potential investors as their institutional structures develop, and competing interests have channels to make their voices heard.

Technical advances: There are still major technical breakthroughs to anticipate in terms of the production of many species in aquaculture. Improved breeding, disease control, monitoring and control systems, and feed protocols will continue to be developed to increase efficiency. This is particularly true for novel marine species, but also applies to some freshwater species where full domestication is not yet complete. Currently, despite the domestication of many species for aquaculture, relatively little is known about the production in aquaculture of some promising marine species in marine environments. These species tend to be carnivorous and identifying an appropriate and economical feed protocol has been challenging. Also, offshore aquaculture systems are still in the development stage, despite the application of learning from pioneering offshore locations and the wealth of experience from inshore protected aquaculture. The major promise here is of mirroring the rapid rate of development seen in other aquacultures, and especially in Atlantic salmon.

Land-based systems: A big question mark hangs over the industrialization of production through land-based recirculating systems. While there are theoretical advantages in terms of control of the growing environment, there are many economic issues to be resolved.

Ongoing commoditization: Tilapia, trout, catfish, salmon, and shrimp markets already have commodity characteristics with associated price volatility; however, some of this will be reduced with better market transparency and information. The growth in processed product opportunities will increase as consumers continue to seek convenient ways of consuming fish.

Branding focus and differentiation: There are several opportunities for improving returns through marketing and distribution. Branding can greatly assist, although there are relatively few points of differentiation for commoditized products such as salmon and shrimp. Premiums are available for products of different sizes, novel types, and in some cases for production characteristics. The adherence to 'sustainable' and responsible production practices can differentiate a product and gain a price premium, although probably in only a very small segment of the marketplace in the US. Fresh, local, organic and other designations offer shelter from commodity prices, although markets can be narrow and there will be additional costs and risks.

Logistical advances: Distribution is critical and ensuring that the logistical pathways operate efficiently is an essential component of any market development exercise. Technological advances here will result in substantial benefit.

Improved production practices: Over the last twenty years aquaculture systems have changed as understanding about species, nutrition, and healthy environments for fish culture have improved. More is understood about diseases and their prevention and much capital has been invested in providing services that improve the quality of juveniles and feed and other inputs. However, there are also many species that are very difficult to domesticate and farm. For example, tuna, a much prized species in many parts of the world, cannot be raised yet as it has proven very difficult to produce viable fingerlings and juveniles. Although aquaculture has been practiced for centuries, the rapid advance of production into new environments and with different production systems requires ongoing research to overcome the myriad of technical issues, each varying with environment and species.

Greater concentration of ownership: The structure of production has changed with large-scale organizations being involved throughout the value chain. There are significant economies of scale and these have encouraged larger production units and vertical integration from hatchery through production and processing to marketing distribution. The development of critical mass is essential for success. This has not happened in the United States.

Geographic domination: Geographic concentration is sharply influenced by natural conditions, technological progress and economies of scale and agglomeration. These regional advantages vary by species. Asia is expected to continue to dominate for warm water species. A growth in production seems likely for South Asia and South America. The US faces major constraints to develop a substantial aquaculture sector.

Trade flows: Growth of incomes in developing countries will increase their propensity to consume animal proteins. This growth in domestic demand for fish and other seafood in these countries will increase pressure on seafood supplies. Some consider that this factor will constrain future Asian seafood exports to the US and EU. This is a complex issue to evaluate. Yes, domestic consumption will increase, but other animal proteins are also becoming cheaper and more available. Also, it is to be expected that the Asian aquaculture sector will continue to improve efficiency as a result of technological and structural advances. China is perhaps a special case. Its exchange rate is anticipated to increase to reflect its growing economic progress, and this will reduce its competitiveness in species in which it is strong.

2.2.1 The US competitive position and potential

The declining competitiveness of the US aquaculture sector is revealed by the data assembled on US aquaculture production. While the quality of these data is very poor, almost every sector has been in decline, and there is a general sense of pessimism about the future.

The United States now imports roughly 84% of its total seafood consumption and domestic aquaculture provides only about 5 percent of the seafood consumed in the United States.[2] Barriers to entry are relatively low resulting in substantial competition for each of the major species and product type markets. The reasons for this relatively low level of self-sufficiency in seafood are several fold.

Suitable sites

Apart from relatively small sections of the northeastern coastline and Alaska there are relatively few ideal sites for inshore marine aquaculture. Alaska is firmly against aquaculture development as it perceives this as a threat to its image of having responsibly managed capture fisheries. There are other constraining physical factors. For example, relatively few locations can support the production of species that require large volumes of high quality water. Larger scale trout production is located in Idaho because of this resource (and even this is under pressure).

Regulation

Many in the industry identify the regulatory framework operating in the US as the most significant constraint on aquaculture production. This regulatory framework comprises federal and state rules that determine where aquaculture production can be located, which species can be produced, the methods utilized for production, the treatment of the production medium, how the products are processed, and how they are distributed to the end user. Aquacultural operations need to comply with Environmental

[2] Source: National Oceanic and Atmospheric Administration, Marine aquaculture policy, June 2011. This figure includes both freshwater and marine production. Not included in this figure is the amount of salmon ranched in Alaska and based on Alaska's salmon stock enhancement program.

Protection Agency (EPA) Concentrated Aquatic Animal Production (CAAP) regulations for water and waste discharge. These regulations apply to those using flow-through or recirculating systems that produce more than 100,000 pounds of fish per year. A National Pollutant Discharge Elimination System (NPDES) permit is required and imposes the responsibility to manage pollution outputs and maintain records of this management. Many states have their own regulations. Regulations are not consistent among states and compliance with these regulations involves a wide range of county, state and federal agencies, implementing a patchwork of rules that frustrate those wishing to invest in aquaculture production and marketing. While various federal and state governments wish to encourage aquaculture production, it has proved very difficult to establish a general environment that is conducive to investment.

A second federal agency, the US Food and Drug Administration (FDA) Center for Veterinary Medicine, approves and regulates all medications, which are most commonly administered in medicated feeds. Drugs are species specific; however, veterinarians can approve the use of extra label prescriptions (drugs approved for human or animals, but not the species being treated) and producers must keep records for the FDA. Currently there are only a handful of drugs available for treating aquaculture species.

The third federal agency to regulate aquaculture production is the Fish and Wildlife Service (FWS), which uses the Lacey Act to regulate the transport of fish and shellfish and assist producers with the control of non-native species and potential predators. This has caused considerable frustration to those involved in supplying live fish markets. The FWS is also concerned about escapes from aquaculture and their impact on native populations.

Marine aquaculture is similarly constrained, both within inshore and state waters (usually 3 miles but further for Florida and California), and offshore in the Exclusive Economic Zone (EEZ) - the area extending 200 miles from the US coast. The federal government has responsibility for the latter, but, as yet, no coherent policy that would facilitate investments in offshore aquaculture has been implemented.[3] Pending proposals face significant challenges from the wide range of interests that seek to constrain marine offshore aquaculture, including states that have to agree to the servicing of offshore facilities through waters within their jurisdiction.[4]

An example - salmon

Belle (2002) listed 33 state, regional, or federal regulatory authorities that in some way or other have an input into how salmon farms in Maine are set up and run.[5] A list of permits required in Washington is provided in Appendix 2. There are two primary reasons for this complexity.

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[3] Proposals for offshore policies have been announced in 2011 by NOAA and by the Department of Commerce. These are currently subject to public comment and discussion. See http://aquaculture.noaa.gov/pdf/doc_aquaculture_policy_2011.pdf and http://aquaculture.noaa.gov/pdf/noaa_aquaculture_policy_2011.pdf.

[4] To underline this two environmental groups filed a lawsuit in early August 2011 against the federal agencies that had granted an Hawaiian company the first commercial offshore aquaculture permit issued in the United States. They allege environmental impacts had not been appropriately assessed.

[5] Belle, S. 2002. Maine Aquaculture. 2002 National Risk Management for Aquaculture Workshop.

- First, the process of salmon farming crosses so many regulatory boundaries. In freshwater there are issues relating to water diversion and discharge, to fish health and the use of non-native species, or fish strains, as well as all the normal building regulations and codes. In saltwater things become even more complex because these same issues become embroiled in issues surrounding the use of our coastal waters.

- Second, salmon farming remains a 'new kid on the block'. It requires exclusive use of small areas of coastal waters that have been accessible to all hitherto. Inevitably, it finds itself in someone's way, or in someone's view, or is perceived as a threat to the status quo. The process of establishing new uses of marine resources has become highly involved, with famers being vulnerable to technical violations of procedure, while regulators ability to act decisively is often compromised by conflicting views and interpretations of the science.

Thus, it may seem that salmon farming is heavily regulated to the point of being unreasonable whereas, in reality, it is as much regulatory complexity — not agency heavy-handedness — that causes most of the frustration. This complexity affects US salmon farmers in three ways:

- First, it inhibits companies from applying for permits to expand. Though aquaculture is an approved use of coastal waters in both Maine and Washington, the process of obtaining approval has become so burdensome that few companies would consider it worth the effort today, especially those that are multinational. It makes more business sense for them to invest elsewhere or to acquire the assets of existing operations, as shown by recent acquisitions in both Maine and Washington. There have been no new salmon farm leases approved or applied for in Washington since the early 1990's. In Maine, only three leases have been approved since 2002, although two more may be approved soon.[6]
- It is emphasized that the process is not yet intolerably burdensome in terms of the requirements that have been imposed by state or federal agencies up to now. These requirements are thorough, but not overly so. The burden stems from the inevitability of opposition by other stakeholders and interest groups at every step of the way, which in turn leads either to rejection of the application, or legal appeal of an approval. The appeal process that follows is lengthy and expensive with no certainty that an approval will be upheld, especially if there has been even a minor procedural misstep by the approving body.
- Second, it affects day-to-day operations by requiring statistical reports, system integrity audits, environmental monitoring, etc. In reality, none of these requirements are unreasonable or an excessive cost burden. But they expose a company's operations to public scrutiny and, with a business like salmon farming that is inherently variable and complex from a regulatory standpoint, those who seek to find fault will often succeed. In turn, this puts pressure on agencies seeking to apply rules reasonably, and on company executives who can never be confident that a lawsuit, whether reasonable or not, will have to be defended. It is not a regulatory climate in which the industry can prosper and this is reflected in its current state.
- Third, it provides almost unlimited scope for lawsuits that challenge the legality of the regulations that are in place. In past years the industry in both Maine and Washington has

[6]Belle, S. personal communication

had to contest lawsuits based on the Endangered Species Act and the Clean Water Act. As with most environmental laws there is a wide margin for interpretation in both acts and of expert opinion on both sides of a case. Salmon farming companies have found it very difficult to run their businesses and develop and implement long term plans in such an uncertain regulatory environment.

There are many examples of the potential cost of the latter problem. For example, in Maine, one of the two salmon producing states, the potential for escapes from salmon farms is a particular source of concern. Native stocks of Atlantic salmon in some rivers in Maine have been determined to be endangered and there is concern that escaped farmed Atlantic salmon of different genetic origin interbreed with them. This would compromise their offspring genetically, and further threaten the native wild stocks.

Scientists hold different opinions on this issue. There are those, including geneticists and wildlife biologists in the agencies with jurisdiction, who subscribe to the concept of what might be called 'genetic contamination'. They postulate that offspring contaminated genetically by genes from non-local strains would be less fit to survive in the local wild conditions. However, there are others who argue almost the opposite, claiming that the assumption that salmon propagated in hatcheries will adversely affect the genetic diversity and fitness of wild fish populations is unproven. This contention is "*clouded by uncertainty leaving it open to interpretation based on opinion and philosophical perspective"* (Williamson 2001[7]).[8]

However, despite this difference of opinion, it has become accepted in Maine and determined by agency mandate that escaped Atlantic salmon that are not of local genetic origin are a threat to the remaining wild salmon in Maine's rivers. Therefore, Maine's salmon farmers are only allowed to use stocks that were domesticated from these wild sources some years ago, despite the fact that strains of Atlantic salmon from Europe have been proven to have superior farm performance. This puts them at a competitive disadvantage with growers elsewhere.

In Washington, the other salmon producing state, there is really only one local issue and that is the question of Atlantic salmon being a non-native species in a region where there are five native species of Pacific salmon. It has been shown over 30 years or so that Atlantic salmon is an easier fish to farm than any of the native Pacific species, and there is documentation going back over 100 years to show that attempts to establish it as a non-native fish for recreational fishing in the Pacific Northwest all failed.[9] These failures and the continued failure of Atlantic salmon to establish self-sustaining runs following escapes from regional salmon farms have led to the general conclusion that Atlantic salmon cannot, or is highly unlikely to, establish outside its native range.

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[7] Williamson, J.H., 2001. Broodstock management for imperiled and other fishes. Pages 397-482 in G.Wedemeyer editor. Fish hatchery Management 2nd edition. American Fisheries Society.

[8] Amend, D.F. James Lannan, Scott LaPatra, Robert G. Piper, William J. McNiel, Charlie Smith and Gary A. Wedemyer. 2003. Another opinion on the role of hatcheries in Pacific Salmon management. World Aquaculture, Vol 33, No. 4, pp 8-10

[9] Ginetz, R.M.J. 2002. On the risk of colonization by Atlantic salmon in BC waters. www.watershed-watch.org/ww/publications/sf/colonization.pdf.

Nevertheless, the possibility of colonization and competition with Pacific salmon has become an issue because groups opposed to salmon farming have continued to press the idea that they could establish under some circumstances, such as continuous escapes from fish farms. The concern is that if that should happen, Atlantic salmon might then displace wild Pacific salmon. Since there are already over 30 other non-native fish species in the region, some of which are proven predators on wild salmon smolts, the priority given to this concern may be misplaced. But it has become an issue and the subject of specific regulations regarding 'escape management plans' that salmon farmers must file with the State of Washington.

Marine salmon aquaculture is located in coastal marine waters in bays or inlets where the water temperature is in a range suitable for salmon, there is good tidal exchange, adequate water depth, and protection from severe weather. A critical feature of such locations is that they are always publicly owned, since there is no private ownership of coastal waters in the US except in a few rare cases where tidelands for shellfish culture were deeded to private owners many years ago. Therefore, state governments are landlords to salmon farmers through their departments with jurisdiction.[10] In this respect salmon farming is similar to cattle grazing on public lands where ranchers lease grazing land from the state or federal government, but quite different from most other forms of agriculture or aquaculture where farmers own the land and ponds they farm.

This difference is critically important because salmon farmers are always dependent on government for the right to do business while governments, in turn, are subject to pressures from others who do not think that public waters should be used for this purpose. Moreover, salmon farms are perceived by some established interests to intrude on existing uses of marine waters, such as commercial fishing and recreational boating. Others object to degradation of landscape value. This has led to pressure on salmon farmers and government to slow development of this new industry, with the result that it is now confined to those few rural areas of Maine and Washington, which slows any future expansion.[11]

Market potential; but a major challenge competing in volume markets

In general, US aquaculture has not been cost competitive. In particular, those products of aquaculture that are commodities (e.g. whiteleg shrimp, Atlantic salmon, tilapia, and pangasius (tra and ba – the main competitors with catfish)) arrive at prices well below the level at which US producers can compete. Frozen shrimp and pangasius arrive from a number of Southeast Asian countries, frozen tilapia comes from China, and Atlantic salmon from Norway, Scotland and Chile (Atlantic salmon is imported in fresh form from some major suppliers). As noted above, many potential advantages accrue to these countries – some have relatively cheap labor to prepare the product for market, others benefit from the economies of aggregation, and others from prudent investment in technologies to improve productivity in production and processing.

[10] In Maine this is the Department of Marine Resources. In Washington it is the Department of Natural Resources.
[11] New designs of cages are now being developed which hold the prospect that in future salmon may be able to be farmed further offshore in more exposed waters. However, to date, the salmon farming industry has been reluctant to embrace this technology with such moves as have occurred being relatively small.

Because of the competition, much of US aquaculture production is destined for niche markets that cannot be easily reached by imported product such as live seafood markets in major metropolitan areas, or local markets. There is little formal description of the size and characteristics of this market. The high level of imports, and doubtful reputation of some of those products, has generated a premium for some products originating from local sources. Other food market niches include pond-side sales to local customers.

Some mention should be made of the more positive features of the market environment for US fish and crustacean farmers. These revolve around the changing world order and the economic growth in some key developing countries. The growth in incomes and increase in demand for protein products already has had a major effect on the demand for protein products and particularly for seafood. This growing demand and the constraint on a matching production response holds out the prospect of higher prices in future years. The realignment of currencies and downward pressure on the US dollar could also reduce the attractiveness of the US market leaving more room for domestic suppliers. It is possible to generate a slightly more optimistic scenario, although this is speculative and warrants much more detailed investigation as many factors could intervene to see ongoing pressure on fish and crustacean farm margins.

While environmentally friendly RAS systems raise considerable media attention, they are an expensive method for producing fish and crustaceans such as whiteleg shrimp and rely on premium prices. RAS systems were featured on a very recent Time magazine cover under the headline 'The end of the line'.[12] This article focused on Australis's Massachusetts-based RAS system for barramundi (a species that in nature spend most of its life in fresh water but migrates to saline waters), much lauded for its environmental merits and, apparently serving a healthy niche market in up-scale retail and food service. However, the article contained these quotes that underline the challenge of US expansion of RAS-based production such as shrimp.

> *"Australis' barramundi has become so popular, in fact, that Goldman has expanded production — but not in Massachusetts. While the closed recirculating system he uses in Turners Falls is an environmentalist's dream, Goldman eventually wanted to reach a larger market at a lower cost, a step that he decided required an outdoor operation on the central coast of Vietnam. That branch, where barramundi are raised in sea cages in a protected bay, isn't quite as green as Turners Falls, but it's cheaper. "……As much as the NGOs would have loved it, [Australis] just couldn't meet the economics of an expensive indoor environment," says Goldman [the owner].*
>
> *"Land-based systems may work for more premium species, and they offer the chance to raise fish close to cities. In New York State, for instance, a company called Local Ocean produces indoor-farmed sea bass and flounder two hours from Manhattan. But such systems are still more experimental than economical."*

To sum up the situation the international aquaculture expert Kevin Fitzsimmons offered the following overview of US aquaculture that underlines its weaknesses.[13] These comments cover aquaculture in general, freshwater and saltwater.

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[12] http://www.time.com/time/health/article/0,8599,2081796,00.html

[13] Waterlines, Winter 2010, Aquafish collaborative research support program, USAID/Oregon State University,

How does aquaculture within the US compare with aquaculture endeavors in other parts of the world?

US aquaculture compares favorably in some respects and some species. We have some leading-edge scientists and technologies and some production systems that are top notch. But in many others aspects, we lag far behind. Our diversity of species is low, the scope of farms is relatively small, and we have only a handful of vertically integrated operations. Europe, Japan, and Korea have many more top-level scientists and labs than we do. China's industry is two orders of magnitude greater than ours. We have excellent breeding programs for rainbow trout, channel catfish, white sturgeon, white shrimp, and Pacific oysters, but that is about it. The really big aquaculture crops: carp, tilapia, salmon, seaweeds, basa, flounders, sea bass, sea bream, yellowtail, cods, mussels, pearls, and clams, all have sophisticated breeding programs conducted abroad. And we are missing out totally on tuna, which will be the next huge sector.

What is your response to the sometimes-heard criticism that US aquaculture scientists should not be supporting industry development in other countries that could become competitors to the US industry?

This criticism mostly comes from people who have not been outside the United States to see the international industry. We almost always learn more than we have to share when abroad. The Norwegians alone have developed as much high technology as the US. The Chinese were doing aquaculture for a millennium before the US was founded. Not a single US scientist was involved in the Genetically Improved Farmed Tilapia (GIFT) program, which won the World Food Prize in 2005. Canada's salmon industry is ten times the size of ours. The anemic state of US commercial aquaculture is due to our limited investment, nothing more. Production costs are higher in Japan, Norway, and Korea, and all have bigger industries than the United States. The European Union (EU) has strict environmental restrictions, but has salmon, sea bass, sea bream, trout, and tuna farms. Vietnam grew its catfish industry to four times the size of the United States', while our catfish farmers argued whether it was really a catfish or not. Catfish farmers complain about imports from Vietnam, not realizing that the United States is one of Vietnam's minor markets, after Russia, the EU, Mexico, China, and the Vietnamese who eat the majority of the fish. The United States needs to invest more in technology, science, and extension support for US farmers. But US farmers also need to be willing to invest more of their own money to catch up, travel to other countries to see how they are successful, and import technology and know-how from abroad.

SECTION 3: AQUACULTURE SYSTEMS

This section was developed with the assistance of our SMEs, especially John Forster. The section on recirculating systems was prepared with the assistance of Michael Timmons. Atlantic salmon are cultured in net cages and there is some exploration of investment in recirculating systems (RAS). Marine shrimp are grown in ponds and RAS. The latter contributes a very small part of marine shrimp output.

3.1 Ponds

Pond culture is the most common type of commercial aquaculture in the US. In 2005, 64% of farms selling aquaculture products had ponds. Their versatility allows for a range of production intensities and species, including bottom dwelling species like shrimp. Ponds do not always require flowing water, they can range in size to best fit the needs of the producer, they supply naturally occurring microbial growth to supplement nutrition, and with low densities aeration is the not necessary. The major drawbacks are the requirement for a large amount of flat land to hold water, disease organisms can flourish under these conditions, stock monitoring is difficult, water quality and stock management is challenging, and pond systems are vulnerable to predation and, in some locations, theft. For shrimp, access to saline water is necessary. In most cases this means a coastal location, although some shrimp in pond production takes place inland using low salinity groundwater (e.g., Alabama).

Site selection is critical. While most pond aquaculture does not require access to large volumes of flowing water, some method of replenishment is required. Historically, in shrimp pond culture there was continuous exchange of water with adjacent estuaries or coastal waters. This practice had negative effects on the coastal environment and has been eliminated since the early 1990s. However, small volumes are exchanged in most coastal ponds in the US, often after treatment. The soil quality and the topography of the region are crucial. Flat topography makes maintaining the pond and harvesting the fish more efficient. Soil nutrients will affect the aquaculture system, therefore clay or soil liners might be used. Ponds themselves come in all sizes and shapes. Most ponds are square, but if that shape does not maximize production on the land other options are available. Large ponds are 5-20 acres or even larger for shrimp and small ponds are fewer than 5 acres. The former are less expensive to build, the latter are easier to maintain. Smaller ponds have less surface air so the temperature is more stable. Also, the reduced surface area and the smaller perimeter make controlling predators easier.

Some of the major challenges facing pond aquaculture come from the difficulty of maintaining optimal growing conditions. Disease organisms flourish in pond conditions, inventory is difficult to measure and there are few tools available to adjust the water conditions. Aeration to increase the levels of dissolved oxygen can be avoided in low-density systems, but is required in higher density systems. Aeration can be used to increase dissolved oxygen at night when photosynthesis does not occur. Other factors such as temperature are harder to control. Larger ponds have more surface area and lead to rapid heat gains and losses. An advantage of pond systems is that fishpond water and sediments become organically enriched, stimulating phytoplankton and microbial growth that can provide supplemental nutrition or, in some cases, all the feed fish need. However, many species are cannibalistic when there is not enough food available, and this can be a problem when producers add additional fingerlings to a pond that is populated with larger fish or if crustacean size is uneven. Therefore, food levels must be monitored and supplemental feed should be used as needed.

All of these factors need to be carefully monitored and adjusted to maintain optimal growing conditions. Pond farmers have the fewest management options available to them. They can ensure that they stock with healthy fingerlings and PLs and vaccination is available to protect from some finfish diseases. In addition, they can aerate and replenish water, although this may involve the extra cost of pumping, and add compounds to ensure that the water has appropriate quality for the species. They can also administer various fish health products in the feed.

In the United States, ponds are the predominant production method for whiteleg shrimp although a small volume of this species is grown in recirculating systems.

In summary, the advantages and disadvantages of controlling water in aquaculture in ponds are as follows.

Advantages

- Do not require access to large volumes of flowing water.
- Fishpond water and sediments become organically enriched stimulating phytoplankton and microbial growth that can provide supplemental nutrition or, in some cases, all the feed fish need.
- Ponds are well suited to bottom dwelling animals such as shrimp.
- Ponds stocked at low density may not require aeration and can provide a significant amount of feed for livestock growth.

Disadvantages

- Require large areas of flat land with soils that hold water, or use of expensive pond liners.
- Disease organisms can flourish under the organically rich conditions and these are hard to control.
- Stock monitoring is difficult because the aquatic livestock can rarely be seen and are hard to sample.
- Photosynthesis can lead to low dissolved oxygen levels at night requiring supplemental aeration.
- At high stocking densities, continuous aeration may be needed.
- Large surface area allows rapid gain or loss of heat.
- Vulnerable to predators and theft.
- Mainly limited to coastal locations for saline water supply.

3.2 Cages or net cages

In 2005, 5% of farms selling aquacultural products had net cages. The investment required for cages and net pens varies depending upon local conditions. In protected lakes, they may require relatively little investment capital, while in some marine environments the investment is higher as the specification must cope with waves, swell, currents, and predators that are more aggressive. The investment cost of developing the infrastructure varies depending upon the location. Not all bodies of water are ideal for aquaculture; the body of water should be protected, with adequate depths and water circulation. Some open water locations are vulnerable to water temperature inversions and very strong currents during periods of severe weather.

The open net mesh allows rapid water exchange, an essential for healthy growing conditions for the fish. Additionally, the cages can easily be replicated as an operation grows. However, the potential for the manager to maintain ideal water conditions is limited. The stock is vulnerable to issues such as algal blooms, low oxygen levels, and adverse water temperatures. Site selection can minimize these issues, although managers must continuously monitor water quality and the health of stock. Efficient feed procedures are essential to ensure that fish are fed to satiation and to avoid wasting feed and causing the accumulation of material under the net cage. Management can involve aeration to mix water at different depths to maintain water quality, the administration of medicated feeds, or the movement of fish into medicated baths for short periods. Many cage systems now involve fallowing for a short period to ensure that there is an opportunity for the floor under the net cage to recover from waste deposits and to break natural parasite cycles. Net pens are used mainly by commercial salmon saltwater operations, although there is a minor use in trout production and offshore ocean cages for shrimp are under experiment in Mexico's Sea of Cortez.

In summary, the advantages and disadvantages of controlling water in aquaculture in cage systems are as follows.

Advantages

- A simple, low cost way to contain fish in a large volume of water.
- Open net meshes allow rapid water exchange leading to healthy growing conditions.
- Can be easily replicated for large-scale development where conditions are right.

Disadvantages

- Requires access to protected bodies of fresh or saltwater with adequate depth and water circulation.
- The control of water quality is limited to aeration and mixing water of different depths.
- All feed must be provided from outside sources.
- Not well suited to bottom dwellers such as shrimp unless substrates are integrated within the cage structure.
- Stock monitoring is more difficult than in raceways, but less so than in ponds.

3.3 Recirculating systems

In 2005 11% of farms selling aquaculture products had recirculating systems. Another 9% of farms had tanks that had no recirculation of water. These are used for batch production and are insignificant in terms of commercial food fish production. Recirculating aquaculture production offers an alternative to pond, raceway, and net cage production with several potential advantages. The systems may be developed to use less water, the aqueous environment can be controlled to meet optimum conditions of growth and fish health, the disposal of waste is more manageable, and the production is available throughout the year. The main disadvantages are the costs of investment compared to other aquaculture methods, the extremely high level of management to ensure that sensitive aquatic animals remain healthy and productive, and the limited market opportunities for aquatic animals that have a much higher cost of production. The relatively short history of RAS has seen mixed results. The landscape is littered with failures over the last 20 years as investors have often underestimated the challenges.

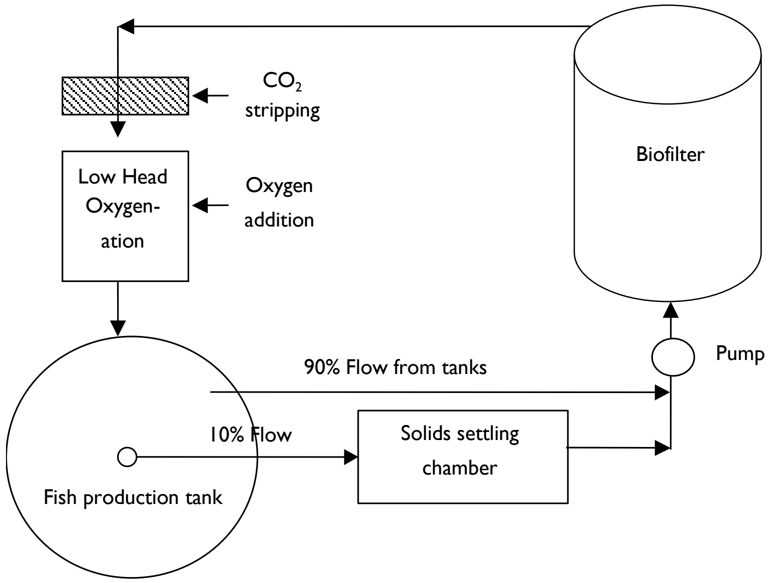
Marine shrimp are being raised in recirculating systems in the US and attracting considerable media attention. Also, Atlantic salmon production in RAS is under detailed consideration. While RAS production of both of these species is very small, some consideration of the technologies is warranted. In very broad terms, the principles of RAS is the same for all species.

RAS has several important considerations that influence potential success. Location is important as there must be adequate farmable water available to the site; good water quality during all stages of production is critical. Management is challenging as several environmental parameters need to be managed to maintain ideal conditions for growth. These include temperature, the concentrations of dissolved oxygen, un-ionized ammonia nitrogen, nitrite–nitrogen, and carbon dioxide in the water. Nitrate concentration, pH, and, alkalinity levels are also important. Feed is a key consideration. Of course, feed composition is critical, but the rate at which it is fed is particularly important in the more intensive systems associated with RAS. Wasted feed and the products of fish metabolism such as carbon dioxide, ammonia/nitrogen, and fecal solids all contribute to the generation of carbon dioxide, and reduce the oxygen content of water. Consequently, these waste products must be effectively removed by filtration systems. Hence, it is critically important to balance the input of feed with the carrying capacity of the containment structure. Overpopulating a tank and reducing the quality of the aqueous environment seriously impacts performance in a recirculating system.

The design of the recirculating system is very important. Tanks must have a flow-through configuration that is suitable for an individual species, and it must adequately clear the system of wastes and replenish it with good quality water for aquaculture production

The success of a commercial aquaculture enterprise depends on providing the optimum environment for rapid growth at the minimum cost of resources and capital. One of the major advantages of intensive recirculation systems is the ability to manage the aquatic environment and critical water quality parameters to optimize fish health and growth rates. Although the aquatic environment is a complex ecosystem consisting of multiple water quality variables, it is fortunate that only a few of these parameters play decisive roles. These critical parameters are temperature, pH and concentrations of dissolved oxygen, ammonia, nitrite, CO2, alkalinity and suspended solids. A generalized unit process diagram for addressing these water quality parameters is shown in Figure 9 on the next page. While this depicts a unit for tilapia production, the basic system components are the same for shrimp RAS. In many ways shrimp RAS is much less developed than finfish RAS. USDA's Marine Shrimp Program is now focused exclusively on developing RAS systems for marine shrimp (*L..Vannamei*).

Figure 9: Unit process flow diagram used to rear tilapia in a RAS



Source: Mike Timmons, Cornell University

Figure 9 demonstrates the commonality of RAS. How these unit processes are implemented depends upon the design approach taken and results in the large variations in individual farm design.

Each individual water quality parameter is important, but it is the aggregate and interrelationship of all the parameters that influence the health and growth rate of the fish or crustaceans.

The diversity of recirculating systems arises from the various design and management approaches taken to achieve targeted water quality conditions. Each water quality parameter interacts with and influences other parameters, sometimes in complex ways. Concentrations of any one parameter that would be harmless in one situation can be toxic in another. For example, when aeration and degassing problems occur, carbon dioxide levels will generally become high, while at the same time dissolved oxygen levels become low. Consequently, the fish or crustaceans are less able to use the oxygen that is available. In fish, the high carbon dioxide level of the water affects its blood capacity to transport oxygen, aggravating the stress imposed by low dissolved oxygen levels.

Another excellent example of the complex interaction among water quality parameters is the relationship between pH and the toxicity of ammonia. The un-ionized fraction of the total ammonia concentration is much more toxic than the ionized form (ammonium) and, at low pH, most of the ammonia in the water is in the non-toxic ionized form. However, increasing the pH by only one unit, i.e., from 6.5 to 7.5, increases the concentration of the toxic un-ionized ammonia concentration by a factor of ten. Simply adding baking soda (or another base) to a system to increase its alkalinity can inadvertently increase the un-ionized ammonia to toxic levels.

The above discussion points out a common failure mode in RAS, which is that animal losses are most often the result of human error. New operators of RAS will often fail to understand the interrelationships of these water quality parameters. A well-designed water quality monitoring system and having staff that understands water chemistry and fish biology will mitigate most of these particular issues.

The relationship between water quality parameters and their effect on fish growth rate and health is complicated. For example, fish and crustaceans lack the means to control their body temperature and maintain it independent of the environment. Environmental temperature changes affect biochemical reactions which lead to different metabolic and oxygen consumption rates. At the lower ranges of the species tolerable temperature range, these rates decrease. As water temperatures increase, some fish become more active and consume more dissolved oxygen, while simultaneously producing more carbon dioxide and other excretory products, such as ammonia. These increasing rates of consumption of necessary elements and production of detrimental elements can have a direct effect on overall fish and crustacean health and survival if these parameters are allowed to exceed normal values. If not corrected, the animals will become stressed to some degree with maximum stress resulting in death. Even low levels of stress can have adverse long-term consequences in the form of reduced growth rates or mortality due to opportunistic organisms that take advantage of the stressed animal.

The needs of individual species may vary and consequently the system must be fine-tuned to deliver optimal and consistent conditions for growth. The engineering of any RAS system is critical to maintaining good quality conditions to ensure that fish health is maintained.

RAS systems have some important positive features.

- Indoor RAS offer the advantage of raising fish and crustaceans in a controlled environment, permitting controlled product growth rates and predictable harvesting schedules. RAS has the advantage of maintaining near optimum water quality conditions for the reared animals. As a result, environmental stress can be minimized and reduced stress translates into the animal's ability to withstand disease challenges.

- RAS conserve energy and water through water re-use after reconditioning by biological filtration using biofilters.

- RAS allow some economies of scale, which results in the highest production per unit area and per unit worker of any aquaculture system, although these may be cancelled by the challenge of managing large complex systems.

- RAS are environmentally sustainable; they use 90-99% less water than conventional aquaculture systems; less than 1% of the land area; and provide for environmentally safe waste management treatment. Many RAS discharge less than 10% of their standing water volume on a daily basis (compared to a traditional flow through system which would discharge 5000% per day, or 50 volumes). Some current commercial RAS are using less water (1 to 3% system discharge per day) where experienced personnel and appropriate technology have been employed. RAS allow year-round production of consistent volumes of product, and complete climate control of the environment.

- Because RAS can be set up to produce the same volume of fish or crustacean every week, week in and week out, they have a competitive advantage over outdoor tank, pond and net cage systems, which are seasonal and sporadic in harvest.

However, in RAS, the stock densities are high and this can result in added stress to the fish. But RAS does not create additional fish health issues; in fact, if proper biosecurity measures and fish health management protocols are followed, disease may be less of a problem. However, if a biosecurity protocol is violated and a pathogenic organism is introduced into a RAS, then there can be very serious and negative impacts, and in the extreme case, the entire farm can be lost. In a typical RAS facility, the rearing environment is recirculated typically between 40 to 60 times per day. So depending upon how many independent systems the farm's inventory is divided into, each subsystem will be almost immediately affected. Conversely, in RAS, if a disease challenge has been identified promptly, the invasive disease can be treated, controlled and eliminated.

Thus far in the United States, RAS systems have been aimed primarily at higher price, niche markets. These may be the live or on-ice product finfish or crustacean markets in metropolitan areas that service recent immigrant populations, or the upscale retail or foodservice trade that seeks to service those seeking local, high-quality products. The costs of recirculating systems are generally higher than for other conventional aquaculture systems. However, the major cost difference arises because investment costs are so much higher. Feed, energy, fingerling, PL and labor costs are very similar. In fact, feed costs may be less than in more conventional systems, as it is easier to match feed to the nutritional needs of the aquatic animal. Also, yields can be higher because of close management of the system. The management complexity involves substantial attention to detail and the investment in appropriate monitoring equipment to ensure that the aqueous environment is never threatened.

For RAS, 90% of losses are due to human error[14], for example:

- Leaving a valve in its non-standard condition (open when should be shut and vice versa);
- Forgetting to do something, e.g., adding some water quality amendment such as sodium bicarbonate;
- Oxygen tank is empty when needed;
- Power is inadvertently shut off (or not turned back on) to some critical life support component;
- Misreading of some water quality parameter and the adding of some chemical to the water to make an adjustment which was not needed; or
- Turning off some monitoring component of the life support system and not turning it back on or part of the monitoring system became non-functional, e.g., dead battery or power outage that also crippled the monitoring alarm system.

If the human error components can be eliminated (through effective design, training, and hiring of competent employees), then there are a myriad of subtle factors that will affect biological and hence economic performance. Biological performance is directly related to water quality. Water quality is directly related to management competence. The best designed RAS can be destroyed by marginal competence being applied by the managers of a RAS.

[14] Timmons, personal communication

RAS-produced animals provide a very small percentage of the aquaculture output in the United States (estimates vary as there are no data describing the use of different systems – some say 5% of the value, others say more).

Perhaps the most important recent development is the growth in the production of salmon smolts in RAS. This is by the far the most extensive usage of RAS technology. Salmon farms use RAS primarily for the increased temperature control (higher temperature) in order to produce a larger stocking smolt, e.g., 60 to 90 grams instead of a 30 to 40 gram animal, and the faster growth allows the salmon farmers to move their stocking smolt to the net pens at earlier dates. Success in smolt production explains why RAS is attractive to the aquaculture industry, e.g., temperature control, disease control and biosecurity employment.

A favorable review of the technology has been undertaken in Canada, and already in Norway there is a rapid conversion of traditional flow-through smolt production systems to RAS. In 2009/10 about 10% of the companies producing smolts in Norway were using full RAS hatchery technology, and it is reported that a high rate of conversion has continued this year. These conversions incorporate some of the most advanced technologies for disinfection, such as UV filters or ozone treatment, oxygenation, and CO_2 stripping. It is reported that this allows production capacities to increase by more than 50% at some sites and the production of larger size smolts for direct stocking in sea cages. The investment cost is high, although there is a strong demand from the farmed Atlantic salmon industry for smolts. The size and concentration of the Norwegian salmon industry and the demand for a large volume of product, have facilitated greater standardization in RAS smolt production systems. Consequently, those involved in ensuring smolt production systems are able to accumulate solid and reliable experience of production history and the impact of perils. Those parts of the US aquaculture industry that are utilizing RAS are likely to be much more heterogeneous and be handling much lower volumes.

Other species using RAS include tilapia (estimated 90% of output), yellow perch (there are some yellow perch growers in the Midwest; one is a multi-million dollar company with plans for expansion[15]). Hybrid striped bass use of RAS is declining as the costs are higher. One company is producing Barramundi in Massachusetts for upscale food service and retail, another pompano fingerlings and several producing ornamental fish (where RAS has been successfully applied).

Some mention should also be made of so-called 'bio-floc' shrimp farming systems. This represents a form of RAS that has been experimented with for several species, but has only had significant commercial application for shrimp. It has received considerable attention in recent years as a number of pioneers have pursued this route in some foreign countries. The concept was developed in Israel and first introduced commercially for shrimp production in Belize. It is now applied commercially in a number of countries including Indonesia, Thailand and China, although it remains a minority form of production. Academic interest is high and some commercial experimentation has been undertaken in the US.

Bio-floc production involves the encouragement of a bacterial community in a pond or raceway. These communities gather in clumps referred to as 'flocs' that consume nitrogenous wastes to convert them into a high-protein feed source for the shrimp. In fact, the flocs comprise a range of bacteria, fungi, microalgae,

[15] This plant purchases private mortality insurance.

and other organisms. Bio-flocs, once established help maintain water conditions and provide nutrition advantages in terms of the costs of water treatment and feed supply. There is reduced need for water exchange and/or treatment and less potential for environmental conflicts. It is also claimed that the system reduces the risk of disease bearing pathogens (including viruses) and involve simplified production systems. Shrimp can be grown at very high intensities in such systems and their feed conversion rate can be very high.

The disadvantages are the high levels of oxygen consumption and energy requirements to operate aerators. Also, the systems require very high husbandry standards as biological conditions must be very closely controlled. Any failure of electrical power can be disastrous as aeration is critical to maintaining the delicate balance of the various bacterial flocs to maintain water quality.

In summary, the advantages and disadvantages of controlling water in aquaculture in recirculating systems are as follows.

Advantages

- Do not require large area of land or a lot of replenishment water.
- Because of this, they can often be located close to the markets they serve.
- Close control of water quality and other variables possible.
- Low discharge volume makes treatment easier and permits for discharge easier to obtain.
- Can be easily replicated for large-scale development where the market will accept higher costs of finished product.
- Especially well-suited to hatchery applications.
- Bio-floc systems can reduce water treatment and feed costs.

Disadvantages

- Costly to build.
- Use substantial amounts of energy for water pumping, aeration and other treatments.
- Depend on continuous operation of mechanical equipment, failure of which can lead to large fish losses.
- Can result in high levels of stress in undomesticated species cultured in high stocking densities.
- Demand high levels of management and investment in system control methods.
- Vulnerable to lower cost competition by producers who have natural advantages and can use one of the other methods.

3.4 Offshore aquaculture

'Offshore' is defined as unsheltered, open marine water. This may mean the use of state or federal waters, although clearly the major issue in the US is the use of federal waters (waters in the Exclusive Economic

Zone - more than 3 miles from the coast except in Florida and Texas). Almost all marine aquaculture in US waters is near-shore, i.e. in protected waters with limited exposure. There is no clear-cut and quantifiable definition of "offshore" as there is a continuum between "near-shore" and "offshore" aquaculture in waters of progressively greater depth, exposure, and distance from shore.

Offshore aquaculture is still at the development stage and volumes produced are very small. The engineering required for offshore cages must be robust to ensure that it can be serviceable in large waves and strong currents. There are some promising technologies and development experience is being gained. The production of sea bass/sea bream in the Mediterranean is probably the most successful large-scale use of offshore technologies. Costs tend to be high as feed has to be transported to the offshore location and labor is required to service the offshore cages.

A number of species have been grown in offshore cages (e.g. cobia, pompano, pacific threadfin), although it has been difficult to identify suitable species that can attract appropriately high prices in US markets and meet environmental concerns about escapes of native species or genetically improved strains. As the costs of offshore aquaculture (both investment and operational costs) tend to be higher, existing opportunities are limited to very high value markets. Development of offshore aquaculture in the United States is heavily constrained by the web of different regulations covering the use of marine resources. This complex regulatory framework reflects the conflicts in use and the overlapping responsibilities of state and federal agencies.

Offshore aquaculture is still at an embryonic stage, and it is unlikely that any significant development can take place around US coasts or within the US Exclusive Economic Zone within the next 20 years, despite recent policy proposals that seek to overcome some of the institutional constraints.

3.5 Biosecurity

For commercial success, an aquaculture operation must maintain aquatic animals at densities far greater than normally found in nature. The animals must survive and grow rapidly. Regardless of the culture system used, the producer must maintain an environment that supports good aquatic animal health. Effective fish health management consists of practices and procedures that emphasize prevention of outbreaks of infectious and non-infectious disease. Implementation of biosecurity practices will reduce operating costs by minimizing the number and severity of infectious disease outbreaks. The following description may be relevant to any type of system, although it is written with reference to the system that demands intense attention to biosecurity – the RAS production. Clearly, some of the issues raised are more difficult or impractical to address in open-air, more extensive systems, but the principles and priorities remain the same.

An effective plan of disease outbreak prevention includes a monitoring protocol that detects fish health problems at an early stage. Running a facility without a prevention plan can be financially catastrophic, as it leads to continual responses to disease outbreaks as the fish health management strategy.

Biosecurity consists of practices and procedures that:

- Reduce the risk that pathogens will be introduced to a facility;

- Reduce the risk that pathogens will spread throughout the facility; and
- Reduce conditions that can increase susceptibility to infection and disease.

Biosecurity cannot completely prevent entry of, or eliminate, all pathogens from any culture facility. Biosecurity accomplishes pathogen reduction rather than pathogen elimination.

Biosecurity is an important part of facility daily operating procedures. Planning should start during the design phase and protocols should be established before the facility comes on line. Adding biosecurity as an afterthought may introduce an additional layer of complexity to an already inefficient operation. Thinking about biosecurity before production begins allows non-intrusive routines to be developed rather than adding stopgap methods after problems arise.

Biosecure RAS husbandry requires that a system be designed so that it can be cleaned completely, easily and frequently. Any surface can serve as a substrate for microorganisms. All components of a recycle system including biofilters, low head oxygenators, CO2 strippers, pipes, and tanks should be constructed of nonporous materials and arranged to be easily accessible for cleaning and disinfection. Clean-outs should be installed to access any part of the system for flushing of accumulated biosolids. Because wood cannot be easily and thoroughly disinfected, it should be considered only for fabrication of disposable temporary structures. Equipment and supplies should never be transferred from other locations to the facility.

Biosecurity is primarily associated with the transport of disease organisms into the RAS. Transport of disease organisms is essentially limited to direct transfer via water, fish/eggs, or animals (human and other mobile creatures) that are carrying water-born organisms on their body or clothes. Aerosol transfer of disease organisms from outside of the facility to inside a facility is really not a consideration, unless the air has travelled over a nearby water body. Viruses that are viral to warm blooded animals are not a threat to fish or crustacean vertebrates. Knowing these few simple facts simplifies what must be addressed in a biosecurity plan: water, feed, fish/eggs and carriers of such organisms that originate in aquatic environments.

- **Water:** Entry of pathogens through a facility water supply is an important route of introduction, and it will increase the risk for infectious disease outbreaks in aquaculture production systems. When possible, a groundwater supply should be used for the facility. Wells and springs do not usually contain resident fish, other aquatic animals, or aquatic invertebrates that could be pathogen carriers. If a pathogen-free water supply is at risk of contamination, or is unavailable, then influent water should be disinfected using ultraviolet radiation or ozonation. Well and spring water may need to be stripped of carbon dioxide and/or nitrogen gas, and oxygen may need to be added prior to using the water for fish culture. For small aquaculture operations of less than 100,000 lb. per year (45,450 kg/yr.), drilled and tested well water is the best choice because it will be specific-pathogen-free, and constant water temperature and flow are more likely than with spring water. For larger operations, well water is also the best choice if an adequate supply is available. Surface waters harbor fish pathogens, and therefore, should be used only as a last resort, and then, only after effective sterilization. If spring water is used, it should be protected from animals that can carry fish pathogens, such as fish, birds, raccoons, salamanders, frogs, and snakes.

- **Eggs/fish:** Entry of pathogens through the introduction of fish to a culture facility is another important risk factor for disease outbreaks in aquaculture. The risk that pathogens will enter a facility can be reduced by purchasing eggs and fish cultured in a disinfected or specific-pathogen-free (SPF) water supply and certified to be SPF or specific pathogen resistant (SPR). Certification involves testing for specific fish pathogens relevant to the species and determining, based on statistical probability, whether they are free of those pathogens. Inspection is usually conducted once or twice per year. In general, in the case of egg purchase, the broodstock would be sampled and certified. In the case of fish purchase, a sub sample of fish would be examined for certification. Other options are maintenance of a pathogen-free broodstock on site and/or use of quarantine before fish are introduced to the production system. For salmon and shrimp the production of SPF and SPR stock is highly specialized and involves a small number of companies.

- **Feed:** Pathogens may be introduced into a recirculating system along with the fish feed. Commercial dry feeds are processed at high temperatures of about 160–180F (71–82C) for steam-pelleted, 180–200F (82–93C) for expanded and 220–350F (104–177C) for extruded feed, so pathogen introduction from this source is unlikely. However, as each bag (or lot) of feed is used, the lot number, and date manufactured and used, should be recorded in case trace back of feed needs to be carried out. To avoid fish health problems related to rancidity or mycotoxins, feed should be used within the time recommended by the manufacturer.

- Introduction of pathogens through live food presents a serious risk of contamination. All live food should be cultured in specific-pathogen-free conditions and should never be used from natural aquatic environments, e.g., ponds.

- **Staff and visitors:** Pathogens can be carried into a facility by staff or visitors (human or animal). Consequently, procedures should be in place to ensure that clothes are changed or protected and procedures fully understood. These procedures should be enforced with no exceptions. For example, employees should be discouraged from having aquatic pets at their homes and from working at another aquatic animal farm during non-work hours. Foot baths should be used at the entry to the production area and changed regularly.

- **Quarantine:** Quarantine is the isolation of newly arrived fish and PLs. This isolation is imposed to prevent the spread of contagious disease to other aquatic animals in the facility. The quarantine facility should be designed for easy cleaning and disinfection. It should be a separate room or facility, not just a tank in the corner of the production facility. Waste discharge should be separate from the overall facility's systems and, if necessary, disinfected with either ozone or ultraviolet radiation prior to discharge or disposal of this water. Access to the quarantine facility should be restricted and additional procedures should be required for all who enter. Quarantine equipment should be clearly marked and used only in the quarantine facility

- Upon arrival, the fish or crustaceans should be examined and all (not just a sample) of the shipment placed into quarantine. Fish should arrive in clean, debris-free shipping water and should be at least average in length and weight for their age and have normal. The fish should be feeding and behaving normally within 24 hours after arrival. For fish, an examination for parasites that includes wet mounts of skin scrapings and gill biopsies should be conducted the day of arrival. To determine which, and how many, tags should be sampled, the supplier should be asked if the fish were all collected from the same rearing unit. For each "lot" of fish, sample at least six fish with normal appearance and six fish with abnormal appearance. Throughout the period in quarantine, moribund fish should be examined for parasites and cultured for bacteria and viruses to determine whether pathogens are present that could threaten the remaining population of apparently healthy fish.

- The quarantine period for finfish is often cited as thirty days. However, quarantine length for an individual facility could be greater or less than 30 days, depending on the species, age, source, and purpose of the fish. It should also account for incubation periods and development times for the pathogens that are known to present a risk, pathogen life cycles, and expression of clinical disease in warm water vs. cold water conditions. Regardless of the quarantine period chosen, the addition of any animal to ongoing quarantine resets the clock to zero.

- One objective of quarantine is to increase the probability that, if the animals are infected with pathogens, an outbreak will occur before they are moved into the production system. Replication time for bacteria, viruses, protozoa and other pathogens is temperature-dependent. The fish need to be exposed to the same conditions, e.g., density, feeding, handling, they will encounter in the production systems, so that a problem may be detected before the fish are moved out of quarantine. A sub sample of animals can be stressed by exposing them for short periods to low dissolved oxygen concentrations, handling, and/or disturbance such as bright lights or motion outside tanks. These conditions will increase the likelihood that an infectious disease outbreak will occur.

- Some protozoal pathogen have a life cycle where some stages occur on and some occur off of (free-living) the fish. In these circumstances, fish can be transferred to a new tank in order to leave behind the free-living stage and reduce the number of parasites that are available to continue the infestation.

3.6 Aquatic animal health products

- A limited number of procedures can be used to maintain health and reduce the threat of disease. Once the disease appears, a number of treatments can be used. Some treatments may involve immersion of the fish in another containment structure, adding compounds to the water, or delivering the compound in feed. There is also increasing interest in pre-and probiotic methods for boosting the fish's ability to resist disease. Vaccination is available for some diseases to boost natural immunity to a disease. In some species, this is administered at the fry or fingerlings stage through a vaccine bath or injection. The vaccines approved for salmonids are shown in Table 3.

Table 3: Approved vaccines for aquatic animal health

True name	Trade name	Diseases	Species
Aeromonas Salmonicida Bacterin	Furogen Dip	Furunculosis (caused by *Aeromonas salmonicida*)	Salmon and trout
Aeromonas Salmonicida-Vibrio Anguillarum-Ordalii-Salmonicida Bacterin	Lipogen Forte	Furunculosis, vibriosis, cold water vibriosis	Salmon and trout
Arthrobacter Vaccine, Live Culture	Renogen	Bacterial kidney disease (caused by *Renibacterium salmoninarum*)	Salmon and trout
Infectious Salmon Anemia Virus Vaccine, Aeromonas Salmonicida-Vibrio Anguillarum-Ordalii-Salmonicida Bacterin, Killed Virus	Forte VI	Infectious Salmon Anemia, furunculosis, vibriosis, cold water vibriosis	Salmon and trout
Yersinia Ruckeri Bacterin	Ermogen	Enteric redmouth disease (caused by *Yersinia ruckeri* serotype 1)	Salmon and trout
Flavobacterium Columnare Bacterin	FryVacc1	Columnaris (caused by *Flavobacterium columnare)*	Salmon and trout
Vibrio Anguillarum-Ordalii Bacterin	Vibrogen 2	Vibriosis (caused by *Vibrio anguillarum* serotypes I and II and *Vibrio ordalii*	Salmon and trout

- A limited number of fully or conditionally FDA-approved drugs can be used for bacterial disease treatment, although some traditional antibiotics may have a positive effect. Fish farmers are advised by FDA to use approved therapeutic drugs as a last resort and to be certain that they are applying the right remedy for a disease issue. These include formalin-based products for control of protozoan parasites, antibiotics for bacterial infections and diseases and anesthetics for use during vaccination or transport. Only formalin-based products are approved for shrimp. Diagnosis is a major challenge in aquaculture and farmers are advised to maintain a close relationship with a qualified fish health specialist. Judicious use and approved dosage is highly recommended as the fish may be destined for food consumption and the wastewater (or local environment in the case of net cages) is subject to discharge conditions. Careful use of these antibiotics is also prudent to avoid the development of resistance.
- The list of approved drugs is relatively small, although the list is growing. A number of compounds are classified as low regulatory priority drugs, and include materials such as acetic acid, fullers earth, sodium chloride, urea, and tannic acid. These are not approved but there is a low enforcement priority (in other words, one is free to use them). Also veterinarians can authorize off label use of an unapproved drug where there may not be an effective approved drug. Finally, there are drugs with deferred regulatory status that can be used carte blanche. These include copper sulfate and potassium permanganate. There is little data on the use of any of these treatments in the industry. Finally, there are some drugs that are experimental that can be used as part of ongoing studies supervised by the US Fish and Wildlife Service's Aquatic Animal Drug Approval Partnership.

3.7 Causes of death in aquaculture

Fish die or are lost from aquatic farms due to several causes. These apply to all aquaculture systems, though they are more serious or difficult to control in some than in others.

- Death due to a wide range of diseases, many factors inducing poor water quality, inadequate nutrition, or what is sometimes called 'trade mortality'; in other words weaker fish just dying earlier in their life cycle than others in the population.
- Death may be due to predation from birds, terrestrial mammals, aquatic mammals, such as otters or seals, or reptiles such as snakes. Where determined predators are present, only partial protection or deterrence is possible in some systems and predation is a significant problem. This is especially the case in open ponds where netting or other protection may not be a failsafe deterrent.
- Losses may be due to escapes, which are a particular vulnerability in net pen systems, though escape at the water outlet is also a possibility in many types of aquaculture, if filters or other barriers fail.
- Losses may be due to escapes because of some failure in the water containment structure.
- Losses may result from severe weather and subsequent impacts. Severe weather and resulting floods may wash out all or part of a containment structure fish population. Some larger fish are susceptible to death from lightning strikes.
- Cannibalism, which is not thought to occur in most farmed fish if they are all about the same size and well fed, may be more common than often assumed, especially if there are a wide variety of sizes. The latter can occur when a fish (or crustacean) population has not been well-graded, or where some pond systems are never fully fallowed between harvests, therefore allowing some larger fish to remain.
- Deliberate culling of weak or 'poor doing' fish' may also be part of the management strategy.
- Human error in operating the equipment and facilities may cause mortality.

SECTION 4: AQUACULTURE INSURANCE

4.1 The previous review of aquaculture insurance

The previous review of aquaculture insurance as part of the NRMFPA covered the key issues associated with the development of an RMA crop insurance plan. The program resulted in three proposed named peril policies that provided insurance against loss of fish production due to mortality. While the NRMFPA proposals related to two freshwater species, the issues raised are all relevant to considering saltwater mortality insurance plans. Hence, we provide a brief background below.

One proposed catfish policy was restricted specifically to cover oxygen depletion due to electricity outage (the catfish power outage policy). This proposed policy was not developed for submission to the Board of the FCIC. The other two proposed draft policies covered catfish in ponds and trout in raceways.

For catfish, the perils covered included oxygen depletion due to power outage, flood[16], and rupture of containment structures due to flooding. An initial proposed inclusion of catfish losses because of a fish harvest ban (unless otherwise indemnified) was excluded from final consideration. Unlike the trout plan, no catfish diseases were included as covered causes of loss, although the initial proposals included several, each of which are influenced by the standard of management.[17]

The named perils in the trout policy included some trout diseases[18] plus oxygen depletion due to electrical outages, flood and damage to containment structures due to flooding, a range of adverse weather (damaging winds, lightning, tornado, and hurricane) and failure of the water supply or oxygen delivery system due to natural causes. Exclusions included inability to market because a buyer refused to accept product, failure of buildings or structures, loss of market value, predation, theft, vandalism, malicious acts, relocation of trout to an uninfected area, removal from the growing location for medical examination and unexplained shortages of inventory value.

The proposed policies borrowed several features of private insurance policies such as detailed applications for insurance, inventory reports, and prompt loss adjustment procedures. The periodic inventory reports were a critical feature as they were to be used as a baseline for identifying losses from a named peril. The value, liability, and indemnity would be based on a predetermined quantity/price table by fish size category for the species.

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[16] It was originally proposed to include losses resulting from windstorm, lightning, tornadoes and hurricanes, and rupture of containment structures due to a wider range of adverse weather.

[17] The original proposal included cover for catfish disease losses from visceral toxicosis of catfish, channel catfish anemia, proliferative gill disease, *Ichthyophthirius multifiliss*, and exotic diseases not found or previously unknown to infect catfish in a commercial setting in the United States.

[18] For trout, the diseases were limited to columnaris (a highly contagious disease resulting from infection by the bacteria *Flavobacterium columnare)*, *Ceratomyxa shasta*, (a microscopic parasite), infectious hematopoietic necrosis (except in Idaho, Oregon, and Washington), and exotic diseases not found or previously unknown to infect trout in a commercial setting in the United States.

The feasibility of extending crop insurance to baitfish and salmon was also examined. Draft policies for these were not submitted to the FCIC Board of Directors. Detailed analysis was not published, however letters to salmon producers gave the following conclusions

The two proposed policies for catfish in ponds and trout in raceways were rejected by the FCIC Board of Directors on the recommendation of RMA staff and following the advice of five separate expert reviews (three did not support the draft policies, two did).

We will touch on several of the aspects covered in the previous study in our report, although here we consider it relevant to recall the conclusions of the five expert reviewers that commented on the proposals prior to their submission to the board. We have not had an opportunity to see the staff paper that accompanied the Board presentation. The results of the expert reviews are summarized below. The first three focused on the conceptual issues while the last two paid attention to the actuarial analysis.

- **Clifton R. Parker** recommended approval of the draft plans as a "very good product" with relatively few criticisms of the feasibility or the policy provisions and supporting documentation.
- **Gary Schnitkey** was highly critical of the conceptual grounding to the proposed plans and recommended rejection of the draft policies, primarily because of the availability of alternative methods of handling the perils covered, threats of moral hazard, and the serious challenge of accurate inventory measurement and reporting. The latter issues were strongly emphasized.
- **Steven C. Griffin** gave a scathing criticism of the proposal because of numerous key items of detailed information that are missing or inconsistent, and the land-based crop insurance framework upon which it was developed. He recommended rejection of the draft policies.
- **David R. Bickerstaff** focused on the actuarial analysis and recommended rejection of the draft policies based on the rating and pricing components.
- **Don Armstrong** focused on actuarial analysis and recommended approval of the program in spite of the "weak actuarial presentation".

4.2 Aquaculture crop insurance – the private insurer's perspective

Insurance serves to transfer risk from one party to another in exchange for a premium via contract. Insurance must be an attractive proposition for both buyers and sellers. In other words, the revenue from premiums must provide a reasonable return to insurance companies and represent good value for money for those buying the product. If the product is unlikely to be profitable, no insurance company is likely to invest in developing or handling the product. If the product does not provide adequate management of aquaculture production risks at a price that is considered to be reasonable, it will not be purchased by aquaculture producers.

From the insurer's point of view, there are a number of key issues[19].

[19] These issues are derived from Paddy Secretan's review of aquatic insurance as part of the NRMPFA.

- The industry has to be of sufficient size to generate revenue to cover all potential costs.
- Identification and measurement of (insured) losses must be clear and objective..
- Where the value of the insured items varies over time, the inventory measurement procedures must have accuracy that warrants insurer confidence in offering policies.
- The environment for aquaculture is inherently very risky.
  - Water is a challenging medium in which to produce anything. Managing water quality represents a major issue when undertaking aquaculture. It is prone to fluctuation in temperature and chemical composition, and is a carrier of both positive (e.g. nutrition) and negative (e.g. diseases and algal blooms) organisms.
  - The range of aquatic animals produced in aquaculture is very large and understanding of critical husbandry issues is lacking in many of these species. Even those species raised in very large volumes on a global basis, such as salmon, marine shrimp, and catfish, **lack the firm scientific foundation of land based animal agriculture** (e.g. porcine, avian, bovine species). The large-scale commercial development of aquaculture based on the application of formal scientific understanding is still recent. For example, the relatively mature Norwegian farmed salmon industry only began in the mid-1980s. For some species produced in aquaculture very little is known and domestication is at a very early stage.
  - Many aquatic animals tend to be sensitive to the conditions in which they are raised. Aquaculture inevitably involves producing aquatic animals in confined conditions in densities that are rarely experienced in natural conditions (or if they are, they move to other locations).
  - Aquaculture production faces a very wide range of perils for consideration as part of aquaculture crop insurance policies. Each demands close definition and **sufficient data to identify rates and other policy parameters**.
- The industry must have adequate support services and well-developed capabilities. Insurance companies need to be confident that management operates at a high level, and potential threats are identified and appropriate husbandry is applied to minimize disruption of production. Poor availability of these support services or a lack of confidence in industry capabilities will influence the availability of insurance or its terms.
- Aquaculture is subject to a very wide range of regulatory controls through federal, state and county agencies. These regulations serve to control a number of key features of aquaculture production. For example, they may restrict the production of a species that can threaten environmental value, control the discharge of wastewater, constrain the use of aquatic animal health drugs, compel the reporting of diseases, restrict the movement of products across state borders, impose treatments or culling in the case of disease threats or outbreaks, and insist on food safety. Each of these regulatory actions will need to be taken account of in constructing appropriate wording for policies.
- Aquaculture is vulnerable to major disease events. This is particularly true of marine aquaculture where disease has struck hard to seriously affect a large part of an industry.

Recently the Chilean salmon industry was very seriously hit by a viral disease and shrimp aquaculture operations have been almost wiped out by viruses in some countries. This threat of large potential losses reduces the incentive for insurance providers to invest in aquaculture insurance.

- Specialist skills must be available within the insurance industry to underwrite the risks and to deal with the issues associated with appropriate servicing of insurance products. The insurance industry's own capabilities are developed with experience. Its experience insuring aquaculture in the United States is limited and the appropriate skills for marketing and servicing policies would need to be developed. Loss adjustment procedures may vary by production system and species produced, and inevitably, specialist aquaculture loss adjustment skills are very thinly distributed.[20] Also, special procedures will need to be developed for reporting and dealing with a claim as aquaculture perils can quickly result in serious outcomes.

- Aquaculture operators should have a strong interest in and willingness to pay for risk management strategies (e.g. crop insurance). With risks being relatively high, one might expect operators to be willing to pay appropriate premiums to cover these risks. However a wide range of factors may reduce this willingness. In particular, very tight margins, as has been the case in US aquaculture in recent years and especially in US shrimp farming, may lead to reluctance to pay for adequate risk management. Also, very small, non-specialist aquaculture operations may consider premium rates too expensive.

- Insurers generally like enterprise sectors that normally provide sound and consistent profits. US aquaculture has failed to produce strong results, and occasionally encounters severe losses from weather or disease events.

Despite the growth in importance of aquaculture as a supplier of seafood, insurers face specific challenges in developing successful products. The challenge for insurers in the United States, with its diverse aquaculture sector comprising very few large commercial-scale operations, is substantial and historically the only private insurance purchased has been brokered locally, but underwritten by insurers based overseas (primarily using the Lloyds insurance market in London) (see Section 4.4.1).

4.3 RMA insurance plan design issues

The previous in-depth review of aquaculture insurance opportunities revealed some key issues associated with aquaculture insurance and our analysis of the feasibility has focused on each of these. The five main issues are insurability, determinability, measurability, actuarial assessment, and other risk management provision. For this review, which includes some less commonly cultured aquatic animals, we add another key issue and that is the size and structure of the industry.

[20] Despite the experience of FSA in administering the NAP program.

4.3.1 Insurability and determinability

Identifying which perils are of concern and differentiating those perils that are insurable from those that are not is a critical issue. Linked to this, it is important that a loss can be linked unambiguously to a specific insured peril.

Insurance can only cover losses incurred by accidental and unintentional events. Moral hazard (behavior representing either fraud or a rational response to having insurance on a crop) can reduce the performance of an insurance plan. Deductibles can reduce behavior that might intentionally cause higher losses. However, it is normal to exclude a peril where management can strongly influence the losses incurred.

Disease

The different named causes of loss in the NRMFPA proposed catfish and trout policies were listed in section 4.1 above. It is of interest that no catfish diseases were considered insurable, and only a limited list of trout diseases.

The previous study focused largely on the identification of disease perils that could be insured. This was a major issue as disease is a leading peril confronting agricultural operators, and a wide range of diseases are experienced in saltwater salmon and marine shrimp farming. These have differing impacts on production and are subject to varying degrees of mitigation through management practices. As noted above, insurance can only be applied to accidental or unintentional perils because of potential problems of moral hazard. In the NRMFPA program, close attention was paid to developing a decision tree that would assist in the identification of disease perils that could be covered. Attention focused on the following key questions: does management influence the potential risk of disease; can the disease be controlled; are losses acute; and, can the disease be identified in the case of loss? The decision tree below (Figure 10) was established as part of the previous study.

Most infectious pathogens are present in aquaculture, although a disease outbreak is usually conditional upon other factors that compromise a host, or the immune system of the host, to give the pathogen an advantage. The most common factor that increases the chance of disease outbreak is stress. Stress can result from a range of different factors.

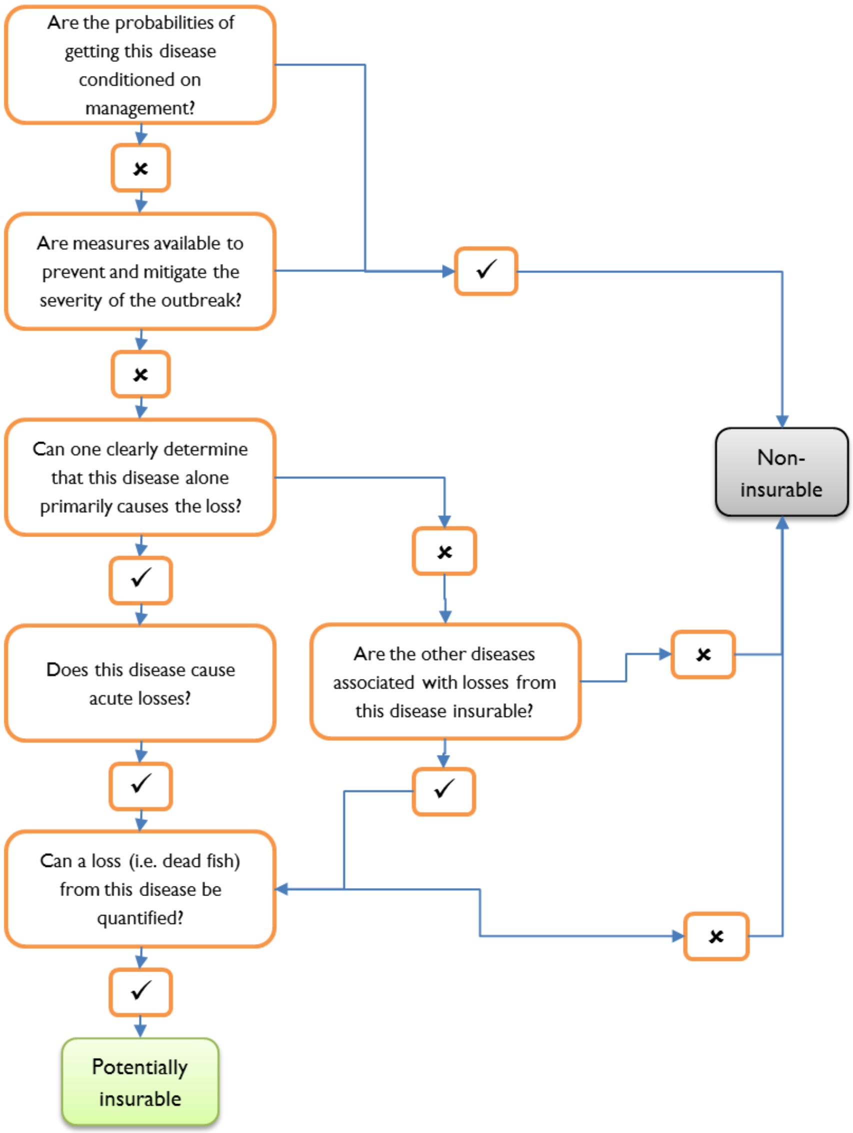
- Chemical sources of stress such as low dissolved oxygen, improper pH, pollution from chemical treatments (accidental or intentional), diet composition (type of protein or other compositional factor), and the accumulation of ammonia or nitrite from metabolic wastes.
- Biological sources of stress such as population density, the presence of other species of aquatic animals that might be aggressive or territorial, the close proximity and contact with animals of the same species, and various microorganisms and parasites.
- Physical sources of stress such as temperature, light, sounds, dissolved gases, handling, shipping, and disease treatments.

Good management practice minimizes each of these sources of stress, ensures that proper sanitation is applied to all of the equipment on a facility, and that operational procedures control the introduction of potentially harmful pathogens. Consequently, a very large number of aquaculture diseases and parasites are conditional on management decisions. For example, vulnerability to disease is influenced by:

- operational decisions (such as those that determine the quality of water and the feeding regime);
- investment decisions (such as those that determine location and the configuration of the aquaculture facilities); and,
- more general organizational decisions (such as maintaining key equipment inventories, equipment maintenance, and biosecurity - including the movement of staff, stock, and vehicles into the facility).

It is clear that diseases should only be included in a crop insurance plan if there is no potential method of controlling or mitigating the disease or if the disease is unknown or considered exotic in commercial practice in the United States (for example, aflatoxin coverage in corn policies in Texas, New Mexico and Oklahoma).

Figure 10: Decision tree for identification of insurable diseases



Predators, theft, and malicious damage

The above list also excludes a number of other perils such as predators, theft and malicious damage as these are all subject to management control. The exposure to these perils is also closely linked to the production system. For example, it is much more difficult to avoid losses to predators in pond systems where large areas have to be protected. However, despite the seriousness of the threat, there are management actions that can control this peril. Theft is a relatively minor irritant[21] and its inclusion as a named cause of loss in an RMA insurance plan would be subject to adverse selection.

[21] See shrimp News International, for example, September 6, 2011.

Oxygen depletion due to nature and weather-related perils

The previous study had identified insurable perils that included oxygen depletion due to exogenous acts of nature, certain diseases, floods and some other risks that are largely beyond the control of the producer. However, the insurability of oxygen depletion because of a power outage was strongly disputed by two of the expert reviewers. Both suggested that the inclusion of this peril was unnecessary as aquaculture operators could handle this risk by purchasing a sufficient number of generators and fuel to sustain them throughout all but the most protracted outages. It was anticipated that sound management of an aquaculture enterprise would include the investment in essential equipment such as this. This study supports the conclusion of the two expert reviewers who made this point.

Some weather-related perils are not subject to management mitigation. In particular, violent weather and its resulting impact may be unavoidable. However, some weather-related perils can be managed. In particular, the management of water flow into ponds can mitigate the effect of temperature as can aeration or methods of circulating water within a containment structure. Naturally, vulnerability to these perils varies considerably among the different types of production system. Indoor RAS systems are protected from many of the weather effects, while ponds, raceways (not used for shrimp or salmon production in the US), and net cages may be particularly susceptible. All systems depend to a certain extent upon the availability of a constant flow of good quality water.

Although flood was included as an insured peril in the proposed NRMFPA provisions for catfish and trout, it is very difficult to understand precisely how such losses might be measured. In the case of a flood, it is highly unlikely that lost fish will be identified. In this case, it would be difficult to measure the loss even if other issues relating to valuation of the loss could be resolved. This opens up considerable opportunities for moral hazard.

Attribution of mortality to an insured peril

A loss must be directly attributed to an insured peril. In aquaculture, a major factor contributing to disease is deterioration in water quality, stress because of overcrowding, poor nutrition, or other local condition. Consequently, it is very challenging to attribute a specific disease loss to an insured disease peril unless that disease is unknown in US commercial aquaculture, or to a disease that is independent of management procedures. This problem of attribution is pervasive in aquaculture. Also, some diseases are not easily identified and accurate diagnosis involves examination by qualified veterinary specialists. We are confident that appropriate diagnostic facilities are available to both the farmed salmon and farmed shrimp production sectors.

The insurability of hatcheries

Our scope of work extends to a review of the possibility of extending crop insurance to hatcheries.

The ownership of the hatchery sector for some species may be highly concentrated, with one or a limited number of hatcheries supplying a large number of producers with eggs or in some cases broodstock.22

22 The 2005 Census of Aquaculture identified the following numbers of hatcheries producing broodstock or eggs:; salmon – 2; and shrimp – 2 (larvae and seed).

Hatchery crop insurance would differ significantly from insurance for fish and crustaceans produced in the main grow-out systems. The hatchery sector is diverse, demanding different protocols for each species. Also, within most species there is significant variation in facilities, techniques, and systems. Hatcheries are highly specialized operations, often focusing on a single species and utilizing scientific methods that need high levels of control of the aquatic environment. Normally the quality of water needs to be very high and intense attention to biosecurity methods is required to ensure that the product is disease free. The process of producing and hatching eggs and nauplii demands close attention to detail. The number of eggs and nauplii that hatch and their survivability as newly hatched fry or post-larvae (PL) varies considerably. High proportions of eggs of some commonly cultured species do not hatch or do not survive their first feeding. Hatcheries will sell their product at different sizes depending on the species.

There are numerous problems in quantifying the product inventory within hatcheries. The period to attain viability and to reach fingerling or PL stage varies by species and production levels will vary depending upon the spawning cycle. Product inventory can vary substantially during the year. Inventory quantification and verification pose a severe challenge in terms of insurability. There are many opportunities for moral hazard given the very short period that the product is in the hatchery and their extreme vulnerability to mortality. In addition, it is difficult to assess a fair market value for either the eggs/nauplii or the fingerlings/PLs that are sold as there are no published representative prices.

Additionally, some salmon hatcheries are part of publicly funded fisheries enhancement programs. The largest is in Alaska where a major program to sustain populations of marine harvested species of Pacific salmon is in place. The Alaskan hatcheries are made up of 20 private nonprofit corporations, 11 state owned hatcheries that are contracted to private nonprofit operators, 2 federal or Bureau of Indian Affairs hatcheries and two state owned and operated hatcheries. Hatcheries are able to recover operational costs through special cost recovery harvests and the salmon enhancement tax. In addition, individual organizations have special contracts with the state for specific funding. Almost 2 billion young salmon are released annually as part of the large-scale Alaskan ocean ranching industry. There are several other federally and state funded salmon hatcheries, most of which are supporting wild.

We conclude that it is extremely difficult to develop a crop insurance plan for the highly specialized species hatcheries sectors that would meet FCIC standards.

4.3.2 Measurability

A viable insurance policy cannot be developed unless it is possible to determine very clearly that a loss has occurred and that it resulted from an insured peril. Also, the size of loss must be measurable using accurate procedures that are acceptable to all parties and repeatable.

The previous NRMFPA study and the terms of reference for this study focused on the development of products defined by species. However, it is clear that the production system is a major factor influencing the feasibility of aquaculture crop insurance. This is because it is easier to measure inventory and losses from an insured peril in some production systems than in others. Inventory measurement is an integral component of aquaculture insurance, serving as a baseline from which to identify losses.

Inventory measurement and verification involves the collection of much data. For example, the previous proposed plan provisions for trout in raceways and catfish in ponds provisions required six inventory value reports during the year. These were required to include all containment structures (identification numbers and locations, GPS coordinates, volumes), date each stock size was stocked, stock sizes, numbers of each stock size, weights of each stock size in each containment structure, price elections, total value of each stock size, and total value of all sizes in the containment structure. Documentary support of inventory value reports that may have been required included a detailed listing of containment structures, unit values, the numbers and the sizes and weights of fish stocked, mortalities, sales and purchases for the three previous crop years, feed purchased, and feed fed.

For professional aquaculture managers the inventory is calculated as a function of the fingerlings placed, feed conversion rates adjusted by movements in and out, and collected mortalities. However, this can be a crude method of estimation, although experienced fish and crustacean farmers with sound record keeping may be able to keep reasonable track of their inventory. Private aquaculture insurance policies require regular inventory estimates. However, many involved in aquaculture will not regularly collect or record inventories, especially if they operate on a small scale or if they operate in systems where inventory is particularly difficult to measure.

The problem of measuring loss is particularly severe when the production system involves ponds. Ponds can vary substantially in size, and it is difficult to establish inventory either by sampling or more intrusive methods, such as seining. Mortality is also challenging to measure as proof of losses cannot necessarily be observed on pond surfaces. In some environmental conditions, dead fish sink to the bottom of the pond and begin to decompose. The problems are amplified when the production system does not involve 'all in-all out', single batch method. For example, in catfish, where production extends from one year to another, a recent survey indicated that only 23% of all catfish production involved batch systems (and 76% of catfish operations released fingerlings into ponds that already had catfish in them).

The proposed provisions for insuring catfish in ponds suggested two methods for estimating catfish losses. One method was used when water temperature went below 26°C. This involved a systematic method of estimating floating mortalities (debris field measurement) with dubious levels of accuracy. A seining method was to be used when water temperatures were not conducive to having 100% of the dead fish floating (below 20°C) or as a method to verify the debris field measurement. This latter method is expensive as it involves employing a custom harvest crew. It should be noted that for some aquatic animals raised in ponds, losses might be obscured by cannibalism. This problem is closely related to the efficiency of feeding; cannibalism may increase when aquatic animals receive insufficient nutrition.

Production of fish in raceways presents an environment that is more conducive to establishing inventory. Raceways are fed by a continuous stream of water that is discharged through filters. These filters need to be cleaned regularly to ensure that the flow of water is maintained. Dead or ailing fish naturally move towards the filters and can be removed for enumeration and examination. In addition, it is relatively easy to identify trout by size in raceways by using separation methods.

Production in cages presents similar inventory assessment problems to production in ponds, although fish can be more easily observed. Regular inspection of cages is part of good management practice and dead and ailing fish can be identified and removed by divers on a regular basis.

Production in recirculating systems is conducive to regular assessment of inventory measurement and losses. Recirculating systems are often indoors, and the operator will be regularly checking the feeding behavior, size and health of the stock, and has the capacity to regularly record inventory. In most cases, this will be a function of the fingerlings entered, feed consumption, and expected growth rate minus the collected mortalities.

An alternative method of identifying the guarantee is to use a production cost approach as applied in the dollar plans that RMA offers. In those plans production cost estimates (usually from crop extension services) provided the basis of production cost parameters together with increments associated with the stages of production. We considered and rejected these, as no representative production cost data can be identified for species grown in aquaculture in the United States.

4.3.3 Inventory measurement

Counting live aquatic animals

Accurate counting of aquatic animals is an ongoing challenge for all sectors of aquaculture for two reasons. First, large numbers of animals are usually involved because, unlike terrestrial farm animals, the fish or crustaceans are harvested when they are quite small (for fish usually between 0.5 – 1.5lbs). Therefore, in order to produce substantial tonnage, tens of thousands and sometimes millions of aquatic animals must be stocked in an on-growing system. It is understood that fish counts are accurate to ±2% to 3%; given the present status of live fish counting systems this can still mean a variance of many thousands of fish. Counts of PLs in shrimp farming are likely to be even less accurate. The shrimp production cycle is much shorter and the animals are much smaller and consequently the only count is of PLs entered and shrimp harvested.

Second, the live fish must be crowded in some way in order to count them. This may mean passing them through a counting machine, or counting them manually as they pass down a channel. In both cases, the fish must move from one containment unit to a new containment unit. Alternatively, a count may be estimated by sub-sampling a population to determine average weight followed by counting of the whole population. All methods are subject to errors. Fish activity as they pass through a counting machine often leads to fish being missed or double counted. Manual counting is vulnerable to human error and fatigue. Sub-sampling to determine average weight has a built-in potential for error depending on the representativeness of the sub-sample, smaller, weaker fish often being less able to avoid a net than the stronger ones.

Further, all the methods of crowding and handling fish in order to count or weigh them are stressful to the fish and may affect growth rate. Consequently, farmers try to complete the process as quickly as possible, and this increases the chances for error. Concern about stressing their fish is one reason why farmers are reluctant to count frequently during the growth cycle. It is normal for no counts to be made during the production cycle and for losses such as those due to escape or predation to go undetected.

Starting inventory

A key starting point for inventory accuracy in grow-out systems is to have as accurate a count as possible of the aquatic animals going into the system, albeit subject to the errors described. Almost all juvenile farm aquatic animals start their lives in hatcheries, which may be a long way from the farm. When they are ready to be stocked they must then be moved in special tanks on a truck or by well boat (salmon).

Before being netted or pumped into the transport container, the aquatic animals are normally counted at the hatchery and then may or may not be re-counted on arrival at the farm and before stocking. Alternatively, hatcheries may use a displacement method – based on the known number or weight of aquatic animals that displaces observed changes in the level of water in standardized transportation tanks.

Since the transport process itself is stressful, there is urgency to complete the stocking as quickly as possible when the fish arrive and therefore reluctance on the part of the farmer to handle them again for counting or weighing. Often, therefore, the hatchery count becomes the starting inventory with a level of accuracy governed by the procedures used at the hatchery and limited by the general difficulties in counting large numbers of live fish explained above. This is particularly true in shrimp farming as farmers would find it very challenging to recount PLs after their delivery and transfer to grow-out ponds.

Errors are especially likely when the fish being stocked are small because de-watering them before weighing a subsample is more difficult to do properly, while small size makes accurate separation and identification in counting machines difficult. Smaller fish are also of lesser value on a per piece basis, so there is less incentive for the hatchery or the farm to take pains to be sure of an accurate count.

Since counts on larger fish are likely to be more accurate, farms that start the on-growing process with larger fish are more likely to start with a reasonably accurate starting number. For example, juvenile salmon (smolts) are usually at least 80g (five to the pound) when stocked in net pens and may be re-counted by machine on entry, especially if delivered by well boat. But, even when counted by machine, there is still a margin of error with many farmers accepting that ±3% is normal despite counting machine manufacturers claims to do better.

Some farms that stock small fish employ a 'nursery' system before stocking them into the main on-growing units to get the fish up to a larger size when they are stronger. This offers the chance to re-count the fish after the nursery stage, which is good practice when it is done.

One major problem has already been alluded to. Some production practices do not involve the raising of single batches of fish and hence the receiving containment structure already includes a fish population. This represents a major challenge to accurate inventory assessments and adds further complicated arithmetic to an already highly uncertain calculation. This is rarely the case in either salmon or shrimp farming as care must be taken in ensuring that ponds and net pens are clear of any stock that might carry disease.

Tracking numbers and biomass during grow-out

Except for deliberate culling, the challenge in the case of all other types of mortality is knowing that it occurred and knowing how many fish were lost. Clearly, it is extremely difficult to know how many fish are lost in instances of predation, escape or cannibalism unless the whole fish population is re-counted from time to time to check inventory numbers. For reasons explained earlier, this is something that farmers are reluctant to do and in some cases, such as in large ponds, it is effectively impossible.[23]

[23] Schemes for the independent certification of responsible management of species farmed (e.g., farmed salmon), which assure buyers that the fish has been grown using best practices, may soon mandate the fish

Even in the case of mortality due to disease or other causes, it is not always easy to recover and count all the dead fish (referred to as "morts") or crustaceans. This is especially so in ponds, but in other aquaculture systems small dead fish can disintegrate quickly, or they may be cannibalized by the others, or other organisms that feed on carrion. It is a part of accepted good aquaculture practice to recover dead fish from the system, count them and establish cause of death. These morts may collect on outlet screens, float or sink to be collected by divers in the case of net pens. In net pens they have to be retrieved from net bottoms by divers. The sinking of morts in ponds depends on the temperature of the water and species. Raceways and RAS offer the best conditions for recovering morts as weak and distressed fish get flushed to outlet filters by the water flow. This must be undertaken regularly to maintain water flow and prevent water fouling. However, it is unlikely that all dead fish are always recovered in all circumstances and the inventory shortfall that results will only be determined if a fish farmer takes pains to do intermediate or harvest counts. Intermediate counting may accompany size grading and separation of finfish stock with different growth characteristics. The separation will involve movement of the stock to another net pen or unit.

No one has found a passive, mechanized way yet to determine total biomass in a fish or crustacean production unit without counting the fish and determining their average weight. There are machines, as described, that will count fish but this always involves crowding and handling of some sort, both of which may cause the animal distress. There are also machines that estimate average weight, where a scanning frame is suspended in the water and, as fish swim through, their weight is estimated from an image of the fish and a prior calibration that relates the image to the weight for the species concerned. Over time, enough fish are thought to swim through the frame in order to estimate an average for the population. Farmers report mixed results with the system but it represents an approach that is promising and recognition by the industry and equipment manufacturers that a passive, mechanized solution to the biomass estimation and tracking challenge is something the industry badly needs.

Commercial aquaculture facilities will utilize regular inventory sampling procedures. The one below is used in raceway production of trout and similar procedures can be adapted for use in cages and recirculating systems for other finfish species such as Atlantic salmon. These procedures are not practical in ponds, and in recirculating systems great care must be taken not to stress the fish. It should be underlined that this procedure is only applicable in operations (or parts of operations) that use single batch production. Unfortunately, multiple batch systems are common to ensure effective utilization of optimal carry capacity.

- Sample counts are conducted monthly to determine fish in and fish out, beginning number of fish, average weight per fish, fish per pound and total weight of fish per raceway (tank) and ending number of fish, average weight per fish, fish per pound and total weight per raceway (tank) at the end of the month.
- When sample counting, the fish should be crowded starting from two-thirds of the way down the length of the tank and moving toward the tank inflow. The smallest, weakest fish will linger toward the outflow of the tank, and are not representative of the general fish population.

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in marine or lake net pens are re-counted **<u>if there is significant evidence that an escape may have occurred</u>**.

- With the fish loosely crowded at the head end of the tank, a sample of fish is netted into a bucket of water suspended from a scale. The weight is recorded and the fish are counted as they are poured back into the tank on the other side of the crowder bar.
- If fish are well graded 5 samples should be sufficient. Samples should be taken to be representative of the population, thus a dip net should be taken from the four corners of the crowed area and from the middle.
- Fish per pound is calculated by dividing the total number of fish from all samples by the total weight of all samples. The calculated fish per pound for each tank is then used to estimate the weight of fish in the entire tank. See Table 4 for an illustration. In this example the sample count for the tank is 8.81 fish per pound. To estimate the total weight of the tank the number of fish in the tank taken from the inventory record is divided by fish per pound. Let's assume there are 20,000 fish in the tank; the total weight is 20,000 ÷ 8.81 = 2,270 pounds.

Table 4: Sample count example

Sample	Weight (pounds)	Number of fish
1	3.5	28
2	4.1	37
3	3.1	28
4	4.9	44
5	3.8	34
Totals	19.4	171
To ensure accuracy the fish per pound is derived by dividing the total number of fish from all samples by the total weight from all samples. i.e. Sample Count = 171 ÷ 19.4 = 8.81 fish per pound		

- To track inventory between monthly sample counts fish are advanced by weight based on the amount of feed fed and previous growth records or a growth formula. Mortality is tracked daily (number and average weight per tank) and subtracted from inventory.

Using proxies

In the absence of reliable mechanization, some aquatic animal farmers use feed consumption as an indicator of biomass, because the amount of feed consumed under different circumstances is reasonably predictable. Therefore, if the population does not consistently eat the expected amount, it is quite likely that there are fewer fish there than records show, which may prompt a re-count or at least a detailed inspection of the system. For this reason, accurate feeding records are very important and may provide an insurance adjuster, in the case of an insurance claim, with a way to check back on the possibility of prior inventory variance. However, the method depends on accurate feeding and sensitive determination of satiation. It is easy to over feed aquatic animals and never know it because wasted feed may be flushed out of the system, fall through net meshes or disintegrate on the bottom of a pond[24]. So much depends on the diligence and sensitive observation of those whose job it is to care for the animals day-to-day and no matter how much new technology is developed that is unlikely to change.

The NRMFPA reviewed closely the use of proxy methods such as those using farmer estimated feed conversion ratios. These methods were rejected because of eight specific objections, most of which were based upon the potential for moral hazard (see NRMFPA report page 43)[25]. The previous feasibility study for catfish and trout has a very strong preference for enumeration and physical measurement of actual losses rather than proxy measures. Undoubtedly, the appropriateness of using proxy measures based primarily on farmer estimated feed conversion might be applicable to some operations in some production systems; however, it is potentially flawed when applied to an industry-wide plan such as that administered by RMA. The problems are magnified when applied to highly heterogeneous aquaculture species sectors. These difficulties are compounded in shrimp production as shrimp nutrition often involves supplementary feed (and in some cases no feeding) as water conditions may be managed to supply sufficient nutrition.

Inventory accuracy

The inventory on a fish or shrimp farm's books usually derives from crude mathematics.

- a count at stocking that is probably accurate to no more than ±3% (and not always undertaken);
- less culled animals and those that have died and been recovered and counted (where that is possible); and
- less an unknown number of animals that may have died and not been recovered, or may have escaped, been cannibalized or predated.

And unless the animals are re-counted at some point during the grow-out process, the variance will increase until a final count is made at harvest. To this we must add the complications arising from the practice of comingling animals (not a problem for shrimp) of different ages to maximize carrying capacity, and the need for some less professional operators to initiate detailed record keeping when they have not done so before.

In general, we remain unconvinced that an appropriate procedure can be identified for use across a species grown within a certain production system. In particular, there are very serious problems identifying inventory and losses in shrimp ponds, and consequently this factor alone works against our support of an insurance plan for all species grown in ponds. For salmon grown in net pens, the level of accuracy is likely to be higher, especially in those parts of the industry where the product is destined for processing and production planning is critical. The sampling system identified above is likely to be appropriate for these

[24] In net cages, it is common to use underwater cameras to monitor satiation and avoid over feeding. This practice has been encouraged to avoid environmental damage as a result of food falling to lake or marine floors.

[25] Factors contributing to misleading estimates include production cycle lasting one year, continuous introduction of fingerlings, potential changes in stocking density, ponds in production, or other management practices, purposeful delay of the last harvest into the following year, misreporting of feed use, adjustments to management practice, and the different feed requirements of different sizes and classes of fish.

companies and for an RMA. It is widely adopted for private mortality insurance in the global farmed salmon industry with the support of feed, other production records and regular site visits and inspections.

4.3.4 Actuarial assessment of data limitations

Actuarial assessment relies on data that can be used to determine premium rates. For example, we need to know:

- How frequently are producers subject to the various perils and what is the likely impact on production?
- How does the probability of loss vary among regions, species, production systems, or different types of managers?
- To what extent are losses for one producer independent of the losses of others (idiosyncratic) or are losses likely to affect producers simultaneously (systemic)?

Where insufficient data is available to classify the relative risks (and premiums for) different categories of producers, it is difficult to determine appropriate premium rates. This may result in adverse selection, with rates that are too low for the poorer risks, and too high for the better risks. Actuarial issues relating to the available data are outlined below.

- The frequency and severity of losses are important in creating an actuarially sound rating plan. These are normally identified from analysis of data that describe the relationship between losses and perils over an appropriate time period. Such data are not available for any aquaculture system or species. There is considerable uncertainty over the potential for loss for different types of perils for most aquaculture species and production systems. In the private market a risk charge to the premium may be introduced to reflect high levels of uncertainty.
- Pooling of different risks reduces the variability in losses for each risk group, and results in more credible premiums. However, there is insufficient aquaculture data available to define separately identifiable risk pools. For the saltwater species, there are an insufficient number of farms in the United States to create a risk pool.
- The willingness to pay premiums varies according to the structure of the business. An aquacultural operator who is highly geared to aquaculture revenue will be much more likely to pay for aquaculture crop insurance than one who has other crops or enterprises. Where sectors are under considerable financial pressure there is going to be less enthusiasm about investing in insurance. The US shrimp sector is under severe pressure from imports.

4.3.5 Data availability

Production history

There is little available data regarding farmed saltwater species in the United States. Our subject matter expert provided data on nine commercial saltwater shrimp farms operating in Texas from 2006 to 2010 (no survivability data are available for 2008). The data included acreage, lbs. harvested, number of PLS introduced and harvested. In addition data was available for each of the ponds on one Florida pond shrimp farm for one year (2010). These data on survivability are shown in Table 5 and Table 6.

On average, roughly 50% of PLs entered into production survive to be harvested in Texas. The lowest survival rate was 42% in 2007 and the highest 65% in 2010. There is no data that shows the reasons for the differences between different farms or between years. The data on the farm in Florida reveal significant variation in pond performance (20% to 59%). The farmer said the low dissolved oxygen was the cause of the low survival ratios for ponds 2 and 5. We do not know the event that caused the low dissolved oxygen. We do not have any other data that describes the cause of loss or the differences in practices for each farm.

Table 5: Survival rate during grow-out on Texas pond shrimp farms.

Farm	2006	2007	2008	2009	2010
1	38%	67%	n.a.	54%	74%
2	44%	21%	n.a.	60%	45%
3	49%	33%	n.a.	64%	47%
4	63%	54%	n.a.	76%	48%
5	43%	43%	n.a.	66%	55%
6	70%	50%	n.a.	n.a.	n.a.
7	n.a.	7%	n.a.	*Ceased production*	
8	37%	29%	n.a.	*Ceased production*	
9	47%	n.a.	n.a.	*Ceased production*	
All	**46%**	**42%**		**65%**	**51%**

Source: G Treece, Texas Aquaculture Association.

Table 6: Survival rate on one Florida farm in 2010

Pond	Survival rate
1	56%
2	26%
3	55%
4	49%
5	20%
6	59%

Source: G Treece, Texas Aquaculture Association.

There is no data on survivability of salmon although our subject matter expert suggests that the industry factor in losses of 10% to 15% in their production planning for the grow-out phase.

Price data

In general, the only price data available cover those aquaculture products that are sold into commodity markets. There are data for salmon and shrimp. However, some shrimp are sold into niche markets as described in the species profiles. There is no regular information collected or reported publicly on any of these local markets. Appendix 1 describes each of the price sources available for the species under review.

The absence of these data seriously compromise the development of crop insurance plans based on guarantees derived from prices and production volumes.

4.3.6 Rating and pricing

Since a rating plan was recently introduced as part of the NRMFPA, we will first discuss that rating plan and the comments provided by expert reviewers. Since the NRMFPA plan was not enacted, we will discuss the shortcomings in the plan and what could be done to address them. The NRMFPA covered catfish grown in ponds which is somewhat similar to the farming of saltwater shrimp. While shrimp represent a different production process with a shorter production cycle, some aspects of the analysis are relevant.

The plan proposed by the NRMFPA was a dollar value plan similar to the cultivated clam pilot insurance program, which was loosely based on the nursery insurance plan. This plan establishes a guarantee based on the number of fish times a price per size of fish. Indemnity is paid when an insured cause of loss causes the inventory to be less than the guarantee. This is similar to an Actual Production History (APH) plan, where the price is established upfront and does not change regardless of the prices at the time of loss. The major difference is that the guarantee for an APH plan is established from historical yields rather than the current inventory value. This difference makes sense for the different plans, although the establishment of the inventory and the loss adjustment process for both clams and nursery are a major concern for both plans.

RMA recently combined different revenue programs into the "Combo" policy. This eliminated the additional work associated with several different revenue plans (Crop Revenue Coverage, Revenue Assurance, and Income Protection). The Combo policy has three options:

- Yield Protection (similar to previous APH plans)
- Revenue Protection (RP)
- Revenue Protection With Harvest Price Exclusion (RP-HPE)

RP insures a grower using APH times a projected price. The prices are based off futures from the commodity markets (e.g. Chicago Board of Trade). If the harvest price is greater than the projected price the grower uses the harvest price in the indemnity calculation. The RP-HPE policy does not adjust the guarantee based on the harvest price.

The APH is currently used for annual commodities that are harvested in a given year; most are also planted in the same calendar or crop year, except for perennial crops. The harvest is typically over in a short period and needs to be completed quickly to avoid quality problems. The major difference in an APH type product for aquaculture would be the lack of a common metric for yield. A field of corn or orchard of apples would be expected to produce a similar yield given the same growing conditions. An aquaculture facility in which young aquatic animals may be added or harvested at different sizes and in some cases intermittently over the course of a grow-out period, may have varying levels of production despite similar growing conditions. How to define a yield is not obvious. Is it pounds of fish or number of fish of different sizes? In any case, it must be related to whatever price data are available. Presumably, it is per unit of water volume in the containment structure, although measurement of volume can be challenging in ponds, and net cage or tank sizes are not standardized. What adjustment is made when the grow-out period is longer than a year? The answers to these questions are not obvious.

Another difference in aquaculture is that the fish can be harvested when it makes sense economically for the farmer. While the fish may be optimal at some point during growth, there needs to be a market for them at the time. In some cases early partial harvesting may take place to fulfill market demand, in other cases harvesting may be delayed. Thus, we do not believe these types of policies are appropriate for aquaculture because the yield guarantee is based off the APH yield and the prices are based off a representative traded price (in most cases related to a traded commodity future). As suggested above, the first of these is a challenging concept for aquaculture, and the second, representative quoted prices do not exist for the markets serviced (with the possible exception of salmon).

RMA administers group risk policies (GRP) which indemnify a grower if the index (typically county yield) is lower than the expected yield. These are typically available in major row crop producing counties for the major crops. A Group Risk Income Protection (GRIP) policy is also available and covers the price risk in a similar manner to the Combo plans. A GRP pilot plan for oysters was introduced in 2010 for many Louisiana counties that compares the expected county landings to the actual county landings. This plan was not offered in 2012 due to the uncertainty caused by the oil spill in the Gulf region. [26] We do not believe these types of policies are appropriate for finfish or crustacean aquaculture because there are no published comparable data for any species or production systems.

There are other indexed plans associated with a rainfall index and vegetation index that also would not be appropriate for aquaculture because the rainfall or vegetation indices would not be correlated to the aquatic animal aquaculture results in any substantive fashion.

There are Average Gross Revenue (AGR) plans that utilize a farmer's latest five historical tax returns to establish an insurance guarantee for a farmer's overall production for a tax year. There is a major limitation to aquaculture growers as only 35% of liability may come from livestock. A similar plan, AGR-Lite, does not have this limitation although the maximum liability amount is much lower than for AGR. AGR is limited to $6.5 million of liability while AGR-Lite is limited to $1.0 million of liability. These plans list aquaculture/fish as an insurable commodity although the plans are not available in many aquaculture locations. However, many states which could possibly grow saltwater shrimp are not eligible for AGR-Lite at this time. The states of Arkansas, Louisiana, Mississippi and Texas are not eligible for AGR-Lite plans (or AGR). Alabama, Arizona, South Carolina and Florida are eligible for AGR-Lite. For salmon, the states of Alaska, Maine, Oregon, and Washington are eligible for AGR-Lite. California is not currently eligible for AGR-Lite, but a few counties are eligible for AGR. A review of AGR and AGR-Lite records since inception in 1999 found only one policy earning premium associated with aquaculture. The policy was in Barnstable, Massachusetts which meant it most likely insured clams or oysters.

RMA administers several plans for livestock including Livestock Gross Margin (LGM) and Livestock Risk Protection (LRP) plans. LGM provides protection against loss of gross margin (market value of livestock minus feed costs). LRP provides protection against price declines affecting livestock value. These plans use values from the commodity markets to set the guarantees and indemnities. While the feed costs could be used for an aquaculture plan, there is no corresponding index for aquaculture prices. However, feed use and composition varies within and among species, especially among shrimp producers operating differing

[26] Informational Memorandum PM-11-009 USDA - RMA

levels of stocking intensity. Also, this would not cover the actual loss of livestock (aquatic animals). It is our understanding that the private insurance market provides livestock coverage for most terrestrial livestock under a Farmowners Insurance Policy.

In the statement of work describing this project, RMA provided the following definition:

> *"Actuarially sound – For the purpose of the Federal Crop Insurance Program, a classification and premium rate determination system, where risk premium collected is sufficient to cover future losses and to build a reasonable amount of reserve."*

The Casualty Actuarial Society provides the following principles with respect to insurance rates: [27]

- A rate is an estimate of the expected value of future costs;
- A rate provides for all costs associated with the transfer of risk;
- A rate provides for the costs associated with an individual risk transfer; and
- A rate is reasonable and not excessive, inadequate, or unfairly discriminatory if it is an actuarially sound estimate of the expected value of all future costs associated with an individual risk transfer.

Expenses are provided under the A&O subsidy, a discussion of which is out of the scope of this project. The RMA definition of actuarially sound as discussed above implies that the long-term loss ratio should be close to but less than 100%.

There are many principles to establishing a sound insurance program. These include:

- Accurate valuation of amount of insurance (liability) and exposure unit,
- Accurate valuation of loss and determination if losses are caused by insured peril
- Credibility and availability of data to build a rating plan
- Insurance plan should mitigate adverse selection and attract high participation rates
- The rates should be similar for risks with similar exposure to perils (homogeneity)

These topics have been discussed in detail in the NRMPFA study, the expert reviews and this report. From a rating standpoint the major obstacle is obtaining credible insurance experience for the proposed program. Ideally, we would want actual indemnities and losses associated with the insurance program. Since there has been no prior program other data may be used to estimate the rating parameters.

The NRMPFA used the results of the NASS cross-sectioned survey of catfish and trout farmers to establish the rates for this purpose.

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[27] Casualty Actuarial Society, *Statement of Principles Regarding Property and Casualty Insurance Ratemaking* (1988).

Two of the expert reviews analyzed the actuarial rating aspect of the NRMFPA catfish and trout proposals. All of their comments could be resolved with fixes within the rating structure. So the final recommendation by RMA to not implement these programs was probably not due solely to the actuarial work. In our review, we note one critical element that was not mentioned in any of the expert reviews. The 'normal' survivability of catfish was approximately 80%.[28] Therefore, if a grower would 'plant' 100 fish, they would expect to harvest only around 80 of them. The others would die from natural causes over the grow-out period. The Pilot Cultivated Clam Policy does include a Survival Factor that would lower the inventory by either 30% or 40% to account for this natural die-off. Without such a factor, the inventory would generally be overstated. This would need to be introduced into any saltwater aquatic animal policy. The survivability for shrimp is approximately 50%. The survivability of salmon in net cages in the US is reported by industry observers to be between 85 and 90% given sound management. Loss levels are higher at the juvenile stage, especially when smolts are entered into net cages for the first time.

Based on the data outlined in Section 4.3.5 for shrimp, the selection of this survivability factor would play a very important role in the insurance product. A survival ratio too high would provide too much coverage and the loss ratio may be high. A survival ratio too low would discourage any grower from buying insurance and low participation rates would follow. Based on the distribution of the survival ratios from one year in the farms (see Table 5 and Table 6) it would be difficult to select a "one size fits all" ratio for an insurance plan. Allowing the producer to provide historical survival ratios may be advisable, but this would open the door to moral hazard as the historical records would be difficult to audit. Regardless, the rates for insuring shrimp may be high due to the wide range of survival ratios shown in the limited data. The amount of premium a grower would pay obviously is a major factor in the decision to buy insurance.

In order to mitigate adverse selection and attract high participation rates, the insurance provided and premium must be attractive to the producer. A classification plan should group like risks together for premium purposes. Although it is difficult for any individual producer to measure their own risk, the producer may have a general idea of historical perils that would be insured under the plan.

Based on our review, we do not believe that credible data exists to build a rating program for an insurance program for saltwater aquaculture. We also believe that the overall number of farming operations for shrimp is too small to create a federal insurance program specifically to cover a few growers who may or may not purchase the insurance. For salmon there also is a limited number of growers in the United States and since private insurance is available and widely used in major foreign salmon production sectors we do not recommend a federal insurance plan. The salmon private insurance may gain additional support due to its availability in other countries which have significantly more production than the United States.

4.3.7 Willingness to pay

It is difficult to identify willingness to pay in the absence of data to (a) identify current production costs and returns and (b) undertake a thorough actuarial analysis to identify rates. There is no information available on the likely level of demand and willingness to pay for insurance. We note that there has not been an intensive effort to seek the development of crop insurance products by any of the participants in the

[28] From the catfish yield verification study undertaken as part of NRMFPA (Appendix I of the NRMFPA insurability report).

industry. There was no protest from the salmon industry when the NRMFPA study for salmon concluded there was no rationale to develop a federal insurance plan. Indeed, private insurance is available and purchased even though we heard of concerns about the cost. Few in the salmon or shrimp industries were aware of the initiative in the last Farm Bill that resulted in this study. The major stimulus for insurance purchase has been the involvement of parties offering finance to aquaculture companies.

4.4 The availability of other methods of managing risk

4.4.1 The status of private aquaculture insurance in the US

In 2003, a review of aquaculture insurance was authored by Paddy Secretan of Aquaculture Underwriting & Management Services as part of the National Risk Management Feasibility Program for Aquaculture. In that study, Secretan provided a comprehensive review of the key factors that frame the aquaculture insurance marketplace for stock mortality coverage. The study confirmed the minimal market penetration within the domestic aquaculture grower community. It reviewed the challenges that underwriters and loss adjusters face in offering coverage to the aquaculture community and underlined the lack of personnel and technical skills within the insurance distribution system for servicing this unique and limited niche market. From the insurers' perspective, the underlying factors highlighted in the 2003 study remain in place.

The availability of insurance at the farm level continues to depend on the risk associated with the particular farmed species and the operators' ability to meet operating standards required by the insurers based on their understanding of and experience in the industry. A farmer needs to demonstrate sound husbandry practices in order to procure insurance. In particular, farmers require a robust method for inventory control, assessment, and recording. These are the essentials to minimize the risk of loss as well as to quantify the magnitude and cause of the loss should a covered stock loss take place during the policy period.

Aquaculture output is vulnerable to poor management and assessing the quality of the management is a major issue given the range of players in the sector. The emergence of third party certification standards has been identified as one institutional factor that might facilitate risk classification and pooling. These certification programs have been developed to respond to consumer demand for greater transparency on production husbandry and processing practices of food products (although some see this development as a method retailers and foodservice operators have of getting environmental NGOs off their back). The Marine Stewardship Council has focused on certification of marine fisheries, but more recently, investment in certification of aquaculture has been prominent, backed by some NGOs and the aquaculture sector. The Global Aquaculture Alliance (a trade group) and the World Wildlife Fund for Nature have been battling for ascendancy. The latter is closely associated with the establishment of the Aquaculture Stewardship Council (an equivalent of the Marine Stewardship Council). Certified aquaculture operators seek higher prices because of the value of assured responsible management. They anticipate that these higher prices will meet the cost of compliance with the standards.

The impact of these standards on the stock mortality insurance marketplace is yet to be determined. In theory, those participating in reputable certification schemes should have sound management practices that have been certified by a third party. In addition to the two mentioned above, there are several alternative certification programs in operation with varying standards. The discussions with underwriters on this topic have yielded mixed reactions. On the one hand, certification does ensure that key management practices are adhered to; on the other hand, participation in the certification process may rule out some of the tools that might prevent or mitigate some perils. There is no evidence that adoption of standards will result in a statistically significant reduction in mortality losses to be used as an underwriting tool for stock coverage.

As in 2003, there continue to be a limited number of insurers willing to entertain the writing of stock mortality coverage.

In 2003, the Secretan study noted that Hartford Insurance was the one US-based insurer that was providing this coverage via their livestock program. They discontinued this program in 2005 due to the small level of premium written and the poor loss experience. In general, there was a relatively low level of interest in the policies, a factor resulting from the relatively limited number of growers in each of the species covered (trout, perch, tilapia, and striped bass). That has left the US market to the UK-based insurers who offer coverage in the US but rely on more robust sales in the international arena to support their aquaculture insurance underwriting units. In particular, the main aquaculture insurance markets are the large, geographically concentrated single species industries such as those in Norway, Scotland, Chile, British Columbia, and the Mediterranean (the first four producing salmon and the latter sea bass/bream). In British Columbia for example, virtually all salmon producers will have mortality insurance.

The major insurers with aquaculture underwriting capacity and expertise are all either UK or Norway based[29], although some have US subsidiaries that could insure US growers on domestic US contracts. Access to the overseas insurers is through an established insurance distribution system that comprises three levels. First, there are retail brokers who work directly with the insured (often the 'neighborhood' agent who may or may not have real expertise in this area). Second, wholesale brokers who may have no real expertise in this area either help place retailers' risks. Third, London brokers help US wholesalers place risks with the London markets. This system is designed to ensure that the broker who is next in line to the insurer has both the expertise and licensing to be able to work with the insurer on technical placements.

As in 2003, few US based insurance brokerages are currently active in this market due to the minimal market opportunity in the US. Given the weak demand, there is little incentive for brokers to enter this market and invest in expertise and infrastructure. It seems likely that growers will routinely rely on their local property and casualty broker who places more routine and generic coverage on their equipment, buildings, etc. Often those sources of insurance coverage do not have the expertise to guide their clients through the unique stock perils associated with an aquacultural production operation such as disease, parasite infestation, cannibalism, temperature fluctuations, plankton blooms, weather events, earthquake, system failures, and pollution.

There are currently only a few retail insurance agents in the entire US who are active enough to promote their presence on the internet as a source of aquaculture insurance (e.g. The Thompson Group in Indiana, and GNW-Evergreen Insurance, and Aquaculture Insurance Exchange (AIE), both in California). However, there are no wholesale agencies that are known to be active in this market at this time. Given the secrecy

[29] The leading companies are GAIC (Global Aquaculture Insurance Consortium) and the London syndicates: Royal Sun Alliance, Sunderland Marine, and Catlin.

inherent in the insurance community, there is no way to know how much stock mortality coverage any of these agents actually write, but conversations with the UK underwriters indicate that there is no dominant broker in the US for this line of business. Therefore it seems likely that the small amount of business that is placed seem to be one-offs with no thought leader or established vendor to help direct the increased market penetration that needs to occur in order to have a robust insurance marketplace. However, we are aware of some larger aquaculture operations and some currently in their planning stage that have expressed an interest in budgeting for stock mortality coverage in their pro forma business plans. This would imply that these larger operations do see the need for this coverage and will consider it as a normal cost of doing business; this is a hopeful sign for the insurance market.

As noted in Secretan's study in 2003, a robust insurance market must have the potential for underwriting profitability; this is a given in the private insurance world. Every insurer is restricted in the amount of insurance it can provide, based on the size and strength of its capital base. If sufficient profit is not potentially available, then other more profitable lines will be sought. The traditional model for a profitable insured portfolio usually requires the ability to aggregate similar risks in order to develop loss experience data and better predict the underwriting risk of loss. The inability to aggregate risks was one of the frustrations that drove Hartford out of the market in 2005. Since then, there has been a rapid diversification in the combination of species and systems in aquaculture with few species gaining substantial volume and scale (with the possible exception of catfish, which had scale but is now contracting under heavy competitive pressure). Recirculating aquaculture systems represent a good example. While recirculating systems offer the potential to farm aquaculture under controlled conditions, there is considerable heterogeneity in the engineering of these systems. As the quality of the engineering is a critical factor influencing performance, it is difficult to aggregate the risks of RAS even when they are the predominant method of producing a single species, such as for example, tilapia.

The combination of heterogeneity of species and production systems represents a major challenge for insurance companies seeking to service the aquaculture sector. A significant investment is required if they are to operate effectively. One consequence is high premium rates as the insurance company has neither the data nor the expertise to assess risks separately for each species.

While an exciting dynamic for the aquaculture industry, this diversification in species and production models makes it much more difficult for the insurer to be able to comfortably forecast potential losses. The result may often be a premium rate that the grower finds excessive and thereby continues to feed this cycle of anemic demand. This limited demand works against the foundational basis of insurance that calls for spreading the risk over a larger number of risks. This dilemma was identified in Secretan's 2003 paper and remains highly applicable in 2011.

We spoke to a number of aquaculture operators. This was an informal survey of attendees at the Aquaculture America conference in New Orleans supplemented by follow-up telephone conversations with ten growers representing trout, tilapia, hybrid striped bass, catfish, and crustacean production. Most of these growers recognize the need for stock mortality coverage but feel that it is too expensive. However, when pressed, few knew how much it would cost. Currently with a very few exceptions, aquaculture operators are not obligated by any third-party requirement to purchase this coverage.

However, while there continues to be a significant number of small family-run aquaculture operators as well as boutique startups, the industry is witnessing some investment by larger and better-financed growers that can take advantage of economies of scale[30]. This trend could increase interest in insurance of the aquaculture output. Significant levels of equity or debt financing should compel the parties to mandate the maintenance of stock mortality coverage to help protect the interest of the holder of that debt or equity. Banks routinely require crop insurance for many key agricultural crop or livestock investments. Prudent management would expect decision makers of companies with stockholders to procure this coverage to protect stockholder value and minimize director malpractice liability exposure.

Inquiries to a number of UK based underwriters in this regard yielded responses indicating that the majority of stock policies issued (internationally) do include a lender loss payee endorsement indicating that a lender required that coverage be placed and the lender's interest in insurance proceeds is formally recognized by endorsement. It would seem that as more growers rely on external sources for funding, they will face the requirement of carrying this coverage and that dynamic might be the single most significant factor that will increase the incidence of stock coverage in the US. Those increased writings should help stimulate more competition within the insurer community which should bring down pricing and perhaps even entice some of the domestic carriers like Hartford to reconsider entry into this market. The increased writings should help increase grower awareness which may then increase broker interest and involvement which should also result in increased writings. Accordingly, the third party mandate of stock mortality coverage in order to finance the growth of the operation may be the single most significant factor in facilitating the development of the market for this coverage.

In addition to banks, feed companies often provide credit to growers during the grow-out phase. They are also third party sources of finance, and may find value in the protection offered by insurance to their lien interest.

In conclusion:

- **From the perspective of the insurer:** The insurers will continue to need their insureds to be able to properly quantify and monitor their stock inventory and loss events and maintain acceptable underwriting standards of operation and control. In the absence of that capability, it is difficult to envision the ability of any insurer to offer insurance protection. However, if the industry matures it would appear likely that it will be operating at a larger scale, and have more sophisticated technical and managerial capabilities. The development of an industry that can illustrate consistent and sound performance is likely to attract more attention from the private insurance industry, especially if there is solid understanding of the factors contributing to success. As yet, the insurer community lacks any comfort dealing with US aquaculture because of its relatively small size and its structural, technical, and managerial diversity. The industries that they do know, salmon and sea bass/bream, operate on a very small scale in the United States and hence there is little familiarity with the bulk of the US aquacultural industry.

[30] The financial record of some of these is disappointing. Several expensive failures have been recorded in larger scale investments (e.g. Kent SeaTech's investment in hybrid striped bass).

- **From the aquaculture operator perspective:** To realize its potential, the aquaculture industry must have a robust risk transfer mechanism in place to protect all parties with a financial interest in the operation. Stock in the water is commonly the most valuable asset of any grower and protection from loss due to weather, disease or other perils is an important part of risk management. If the industry matures and the growers become larger, more sophisticated, and more dependent on external financing, stock mortality coverage should become more of a routine part of any comprehensive insurance program. However, the tools to manage and measure inventory and stock loss events are poorly developed and consequently those involved in aquaculture will have a difficult time finding insurance capacity. Thus, much of the challenge in providing aquaculture insurance lies in the extent to which systems can be devised to provide credible and reliable inventory and loss measurement systems that increase confidence of those prepared to offer crop insurance.

4.4.2 Federal or state programs

US farms benefit from a web of federal government programs designed to provide a safety net that protects them from the vagaries of substantial production and marketing risks. These are classified as risk management, disaster assistance, or commodity programs. Unlike crop agriculture, aquaculture does not benefit from farm commodity programs. However, some of the risk management and disaster assistance policies are available to those involved in aquaculture.

Risk management programs

Aquaculture is sparsely covered by crop insurance. We discuss the various relevant RMA plans in Section 4.3.6.

The Non-insured Crop Disaster Assistance Program (NAP) provides assistance for farmers that are not covered by crop insurance plans. Eligible producers are those with adjusted gross incomes less than $500,000. Payments are limited to $100,000 per crop year. This program is administered by the Farm Service Agency (FSA). The NAP limits losses from natural disasters and it is available to aquaculture. NAP coverage pays for the loss of value in excess of 50% of the total value. NAP payments are then made at 55% of the established market price (each FSA state committee prepares tables that provide indicative average market prices for all agricultural products).[31] Consequently, NAP provides similar levels of coverage to that offered under MPCI catastrophic protection. There is no information available on the participation of aquaculture enterprises in NAP, nor is there data available on the indemnities paid.[32] While shrimp producers are eligible for NAP, we are unable to confirm whether offshore salmon farms can

[31] See as described in Shields, DA, A Whole-Farm Crop Disaster Program:, Supplemental Revenue Assistance Payments, (SURE), Congressional Research Service, December 3, 2010. Shields notes "Determining prices used in the guarantee and farm revenue calculations has also been challenging. USDA's National Agricultural Statistics Service publishes average prices for major crops and some specialty crops. For some additional specialty crops, USDA's Market News Service reports daily or weekly prices but does not tabulate average prices weighted by volume. For minor and/or thinly traded crops, USDA may find it difficult to gather enough data to determine average prices for both the revenue and the guarantee calculation. However, USDA reports that FSA's state committees have considerable experience developing prices for NAP crops, using a variety of sources such as extension agents."

[32] FSA informed me that these data were not available analysis.

participate. This also applies to the various disaster programs listed below. Our suspicion is that they are as an 'eligible producer' in the legislation is defined as someone that "assumes the production and market risks associated with the agricultural production of crops or livestock".

Disaster assistance programs

Various supplemental disaster assistance programs provide some compensation for losses incurred when weather-related losses are not covered by other programs. The 2008 farm bill included authorization and funding for five new disaster programs to operate until the end of 2011. These new programs replace the ad hoc system of providing emergency assistance to farmers and ranchers and represent a more coordinated and consistent approach. These programs are subject to limits on the payments to individual farm operations.

The largest disaster program is the **Supplemental Revenue Assistance Payments Program (SURE)**, which was developed to provide eligible producers with compensation for a portion of crop losses that are not eligible for indemnity payments under either crop insurance programs or NAP. When a disaster or emergency is declared by the Secretary of Agriculture within a specific geographical region, SURE indemnities can be claimed. Losses are assessed on the basis of total farm revenue rather than losses incurred on a specific crop. SURE compares a farmer's revenue from all crops in all counties with a guaranteed level that is computed from expected or average yields and prices. If the former is less than the latter, the producer receives a payment calculated at 60% of the difference between the two amounts. SURE is available to all farms that are eligible for crop insurance or NAP.

One complementary program can be used by aquaculturalists. The **Emergency Assistance for Livestock, Honey Bees, & Farm-raised Fish (ELAP)** program was authorized by the Food, Conservation, and Energy Act of 2008. Eligible livestock, honey bee and farm-raised fish producers can receive emergency assistance because of losses due to disease, adverse weather, or other conditions, including but not limited to blizzards and wildfires, as determined by the Secretary. This assistance covers feed losses as well as actual livestock, honey bee or farm-raised fish losses.

All aquaculture species are eligible for feed loss assistance under ELAP. This is based on 60% of the producer's actual feed costs for the fish that were damaged or destroyed during eligible adverse weather conditions. However, only baitfish and game fish (often a mix of suitable species) are eligible for payments for losses due to fish death. This is calculated based on 60% of the producer's actual replacement cost of game fish that died in the adverse weather condition. The ELAP program caps assistance at 95% of maximum losses.

In order to be eligible, producers must have insurance for the crop, and if there is not insurance available, then they must have NAP coverage. In 2008, producers could pay a buy-in fee which exempted them from the requirement to obtain coverage from NAP or crop insurance. Eligible producers must file a notice of loss and an application for benefits, following the weather event. This program replaced USDA's **Livestock Compensation Program (LCP)** that compensated livestock producers for feed and pasture losses for eligible adverse weather conditions from 2005-2007. It also replaced the Catfish Grant Program, which provided grants to states that have catfish producers that suffered catfish feed losses. This latter program was administered by the states.

Animal health indemnifications

In addition to the disaster assistance provisions, the Animal and Plant Health Inspection Service (APHIS) offers assistance in cases where serious disease has impacted a specific aquaculture sector. In cases where aggressive depopulation of affected aquatic animal containment structures is required, fish farmers have been indemnified against losses and provided with additional support to combat future infection. For example, a federal program was implemented in Maine following the outbreak of Infectious Salmon Anemia (ISA) in 2001. The establishment of an indemnification program facilitates the control and eradication of highly damaging diseases such as ISA in salmon, foot and mouth disease in cattle, and Newcastle disease in poultry. In the case of ISA, payments of up to 60% of the fair market value of the fish destroyed because of ISA were made and 60% of the cost of carcass disposal, facility cleaning, and disinfection. This level of payment was initially slightly higher than that provided by the regulations in 9 CFR part 53 which covers most other animal diseases in order to gain producer cooperation in depopulating affected fish. The federal share of these costs was later reduced to 40% in the second year of the program. The program was implemented as ISA was considered an exotic (foreign) disease and this was the first time that it had been diagnosed in the United States. The disease was not diagnosed in other parts of the United States.

Aquaculture grants

The **National Marine Aquaculture Initiative**, through the National Oceanic and Atmospheric Administration (NOAA) has two competitive grant opportunities: Aquaculture Research and Aquaculture Extension and Technology Transfer. There was $6 million in funding for the aquaculture research efforts and $4.8 million in funding for aquaculture extension efforts. Both of these programs are supposed to support the development of environmentally and economically sustainable aquaculture, but the focus changes annually. The most recent competition was focused on "Safe and Sustainable Seafood Supply."

NOAA and the Department of Commerce have a joint opportunity for small businesses through the **Small Business Innovative Research (SBIR) Program**. Research topics include: ecosystems, climate, weather and water, and commerce and transportation. The USDA also funds SBIR projects. The topic areas covered by the USDA are: food safety, childhood obesity, climate change, food security, and sustainable energy.

The **Saltonstall-Kennedy Grant Program** is a competitive grant program through the National Marine Fisheries Service that funds research and development projects that will benefit the US fishing industry. Most of the projects funded focus on business start-up or infrastructure development. Each year there are different program priorities.

The American Recovery and Reinvestment Act funds were used by the Farm Service Agency to provide grants to State Departments of Agriculture through the **2008 Aquaculture Grant Program** which assisted producers that experienced losses associated with high feed costs in 2008. There were two goals of this program, to support productive farms and enhance the competitiveness and sustainability of rural and farm economies. Producers that received money from this program were ineligible for funds from any other disaster relief program.

The **Trade Adjustment Assistance (TAA) for Farmers Program** provides eligible producers and fishermen with technical training and cash benefits if their crops have been adversely affected by imports.

For a product to be eligible it must decline in value by 15% over the course of one year, compared to the average value over the three previous years.

Catfish Farmers of America and the Southern Shrimp Alliance submitted petitions stating that increased imports of catfish and shrimp lead to price declines. For shrimp producers the decline occurred in 2008 and for catfish producers in 2009. Both of these petitions were approved.

As a result, individual catfish and shrimp producers can apply for technical training and cash benefits. The technical training helps producers develop and implement business adjustment plans. They can receive $4,000 to implement a plan or develop a longer-term business plan. Producers that develop longer-term business plans are eligible to receive another $4,000 to implement the plan. TAA participants cannot receive more than $12,000 over three years.

Financing

The **Fisheries Finance Program** is long-term financing that can be used for aquacultural facilities as well as other capture fishery costs. Refinancing is also available for existing debt through this program.

SECTION 5: BRIEF PROFILE OF EACH SPECIES

The following subsections describe the status of the culture of the species under review in the United States and outlines key considerations in relation to insurance covering mortality. The detail provided varies by species. A salmon profile was prepared for the NRMFPA and here is updated and presented in a slightly modified form by its original author, John Forster, who also assembled the data on the status of other marine finfish species.

5.1 US farming of marine finfish species for food

A summary of the estimated commercial aquaculture of finfish in the US coastal states is given in Table 7. Details of how and where this was produced and the sources of the information are provided in Table 8.

Table 7: Estimated production summary for US marine food fish aquaculture, 2010, pounds

Species	Scientific name	Total US
Atlantic salmon	Salmon salar	45,500,000
Red drum	Sciaenops ocellatus	2,500,000
Moi	Polydactylus sexfilis	<300,000
Amberjack/Yellow tail	Seriola rivoliana	<200,000
Summer flounder	Palalychthis dentatus	Roughly 100,000
Sea Bream	Sparus aurata	Roughly 100,000
Cod	Gadus morhua	66,000
Halibut	Hippoglossus hippoglossus	20,000
Southern flounder	Paralychthis lethostigma	<100,000
Florida pompano	Trachinotus carolinus	small quantity
White sea bass	Astrocoscion nobilis	0
Black sea bass	Centropristis striata	0
European sea bass	Dicentrarchus labrax	0

Atlantic salmon is by far the dominant species. Its production is described in the species profile below. Red drum or 'redfish' are second but a long way behind. Others are substantially below this. Reasons for the low level of production of other species include:

- The technology for farming other cold water marine fish that could do well in Maine and Washington such as cod, black cod (sablefish), haddock and halibut is still at a research and development stage. Production is very small. Halibut do not appear to be well suited to net pen culture and research focuses on culture in land-based tanks, a more costly alternative.
- Cod and haddock usually sell for lower market prices than salmon, black cod and halibut. This, and their lower fillet yield (proportion of edible meat) means that they must be produced inexpensively if they are to become successful aquaculture species. While cod farming has attracted media attention, some pioneers of this species in other countries have moved to species with more promise.
- Apart from Maine and Washington (and Alaska where marine aquaculture is prohibited), suitable sites for conventional net pens are either unavailable or are used for other purposes.

Consequently, extension of marine finfish farming is only possible in coastal ponds, offshore (open ocean) cages, or in land-based tanks, which are usually RAS.

- Each of these alternative methods of farming are limited in their potential presently because:
  - There are only limited suitable sites available for coastal ponds due to other coastal development or conservation.
  - Offshore cage design is still developmental, resulting in higher costs and increased risks.
  - RAS is technically feasible, but expensive because of the investment cost.
- Knowledge about the farming of most of the other species is provided in Sections 5.4 to 5.6 below. Farming of these species is much less extensive than it is for species with a longer history of culture in intensive, science-based aquaculture.
- As noted in Section 2.2.1, US regulations are not conducive to aquaculture development. This is unlikely to change until agency mandates and policies are clarified and there is clear political support for marine aquaculture.

Further details about salmon and other minor species of marine finfish farming are provided in the sections below. Marine shrimp production in ponds is also covered.

Table 8: US marine finfish farming for food by state

State	Species	Production (lbs) 2010	Method	Source & notes
Hawaii	Moi Amberjack	2009 production is most recent figure reported to be 821,000 lbs total for all species.	Mostly net pens	Hawaii Farm Facts – 2010. 2010 production will be much less. One farm is closed temporarily, the other is re-equipping. Oceanic Institute produces Moi juveniles for commercial growers. Minor quantities of other species such as black cod are produced by the NEHLA facility (Hawaii Natural Energy Lab.)
Alaska	Pacific salmon			See Section 5.2. If Alaska's 'Ocean Ranched' salmon are included, it produces more marine fish by aquaculture than any state in the US. Almost 2 billion juveniles are released and they represent 49% of the total Alaskan ocean harvest.
Washington	Atlantic salmon	18,500,000	Net pens	Washington Dept. of Fish and Wildlife
Oregon	-	0		Paul Olin, UC San Diego
California	-	0		Paul Olin, UC San Diego Substantial quantities of white sea bass juveniles are produced at the Hubbs hatchery in Carlsbad, mostly for restocking but some for commercial sale. The company 'Local Oceans' will reportedly build an RAS farm in California to farm some of their several species.
Texas	Red Drum	2,500,000	Ponds	Granville Treece (Texas Aquaculture 2011) confirmed by Jim Ekstrom. Water sources are either bay water or saline ground water. Texas Parks & Wildlife Dept. produced 23 million red drum, spotted sea trout and flounder juveniles for fisheries enhancement (Joe Hendrix)
Louisiana	-	0		Joe Hendrix, Seafish Mariculture
Alabama	-	0		Joe Hendrix
Florida	Pompano Red Drum, Spotted Sea	0 ?	Tanks	Paul Zajicek, Florida Dept. of Agriculture One land-based farm reportedly producing a small volume of pompano (rumored recently to be going out of business).

State	Species	Production (lbs) 2010	Method	Source & notes
	Trout, Common snook Cobia			A consortium of seven partners led by the Florida Fish and Wildlife Conservation Commission to produce marine sport fish for marine stock enhancement is working to secure funding to support their efforts. Univ. Miami producing 200,000 juveniles per year for sale to Caribbean and S. Atlantic farms.
Georgia	-	0		George Nardi – Great Bay Aquaculture
S. Carolina		0		George Nardi – Great Bay Aquaculture
N. Carolina	Southern Flounder	<100,000		George Nardi – Great Bay Aquaculture All farmed in tanks
Virginia	-	0		George Nardi – Great Bay Aquaculture
Maryland	-	0		George Nardi – Great Bay Aquaculture
Delaware	-	0		George Nardi – Great Bay Aquaculture
New Jersey	-	0		George Nardi – Great Bay Aquaculture
New York	Sea bream & Summer flounder	200,000	RAS	George Nardi – Great Bay Aquaculture Volume will increase to 600,000 lbs in 2011 and 1,200,000 lbs in 2012 with addition of sea bass and yellowtail.
Rhode Island		0		George Nardi – Great Bay Aquaculture
Mass.		0		George Nardi – Great Bay Aquaculture
New Hampshire		0		George Nardi – Great Bay Aquaculture Research quantities of cod and halibut are produce by UNH in its offshore aquaculture program.
Maine	Atlantic salmon	27,000,000	Net pens	Maine Department of Marine Resources & Sebastian Belle Great Bay Aquaculture supplies juveniles of several species to Local Ocean and other growers.
	Cod	66,000	Net pens	George Nardi – Great Bay Aquaculture
	Halibut	20,000	RAS	George Nardi – Great Bay Aquaculture

5.2 Atlantic salmon (*salmo salar)*

5.2.1 Status and trends

Atlantic salmon are farmed commercially in only two areas of the US - Maine and Washington.[33] The industries in these states represent a small part of a much larger global business that has developed and grown consistently over the last 30 years. This development has often been turbulent with trade disputes, ownership consolidation, and conflicts with groups opposed to salmon farming being among the challenges in the business. At the same time, the industry confronts normal food production perils such as disease, and extremes of natural conditions such as weather and the ocean environment. Salmon farming is an inherently risky business, though salmon farmers increasingly manage their businesses to handle these risks and despite peaks and troughs in profitability, have prospered over the long term.

[33] The term 'commercially farmed' means that salmon are grown all the way through to market size in captivity by private commercial growers. We exclude the ocean ranching of Pacific salmon in Alaska. There are also large hatcheries in Washington, Oregon, California and Maine that raise juvenile salmon for release to enhance or restore wild salmon fisheries.

History

Serious attempts to farm salmon began in the early 1970s in Norway, Scotland, and, in Washington State in the US. Atlantic salmon was the species of choice in Europe while coho salmon was chosen in Washington from the five different species of salmon native to the US West Coast. Only limited volumes of salmon were produced as the pioneer farmers developed their methods and markets. In 1980 total world production was only 7,000 metric tons (mt).[34]

In the early 1980s, production volumes began to increase, especially in Norway where conditions in fjords were found to be ideal for Atlantic salmon farm development. In searching for new markets for these increased volumes, Norwegian salmon farmers began shipping fresh salmon to the US by air to meet demand during months when fresh wild-caught Pacific salmon were not available. Initially they were promoted as a 'fresh, out of season' delicacy. They were well received by the market, being especially popular in upscale restaurants where US interest in fresh seafood was awakening. The farmed fish commanded premium prices and shipments from Norway grew.

This success encouraged local efforts to farm salmon in Maine and Washington, and in New Brunswick and British Columbia, Canada. These efforts continued on a small scale for several years, including during the very early years of the production of coho salmon in Washington State. It was not until the early 1980s that Atlantic salmon was identified as clearly the best species to farm, and local private, corporate, and foreign investors on both US coasts pursued this new opportunity. Key events were:

- Construction of large new hatcheries for Atlantic salmon based on Norwegian technology and, in many cases, with Norwegian capital.
- Demonstration that Atlantic salmon could be grown on the West Coast in the Pacific, even though it was not native to the region, and that it would not establish itself in the wild and compete with the native Pacific species.[35] Initiatives to grow Chinook and coho salmon were made at this time also. These continue today on a very small scale, but farmed Atlantic salmon has become by far the dominant species of both farmed and wild-caught salmon. The estimated global production of Atlantic salmon in 2009 was roughly 1.3 million metric tons, compared with 1.1. million metric tons for all other salmon species (predominantly wild harvest).
- Major improvement in the design of cages (net pens) and the equipment to support them that allowed the development of larger farms in more exposed sites.

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[34] Alaska Seafood Marketing Institute, 1992. Salmon Yearbook 1992.34 p.

[35] Some who are opposed to the development of salmon farming dispute this and it is a point of contention in both Washington and British Columbia. Further information on this issue is available in the following references: BC Salmon Aquaculture Review, 1997. Environmental Assessment Office, Canada, BC. http://www.eao.gov.bc.ca/project/aquacult/salmon/home.htm; The Net-pen Salmon Farming Industry in the Pacific Northwest, 2001. NOAA Technical Memorandum NMFS-NWFC-49. http://www.nwfsc.noaa.gov/pubs/tm/tm49/Tm49.pdf or http://www.wfga.net/documents/NMFSRISK.pdf; Review of Potential Impacts of Atlantic Salmon on Puget Sound Chinook Salmon and Hood Canal Summer-Run Chum Salmon Evolutionarily Significant Units. http://www.nwfsc.noaa.gov/pubs/tm/tm53/tm53.pdf

- Suitable coastal farming sites in the US were limited because of the specific characteristics required for success. In some cases, especially in British Columbia (where conditions were more conducive), there was concern that investment and expansion were moving too fast.
- Continued acceptance of fresh-farmed salmon by the market, which resulted in high prices and continued investment enthusiasm.

The success of the industry in the Northern Hemisphere also stimulated interest to the South, especially in Chile where there were ample suitable sheltered, inshore sites, and where most early production was of coho salmon. Coho salmon was also being farmed in Japan at that time, though this industry has declined substantially in importance.

Expansion also continued in Europe, where Norway extended its global dominance, and production from Scotland also became increasingly important. By 1990, global production had increased to over 260,000 metric tons, thirty-seven times more than was produced only a decade earlier.

In 1989/90, for the first time, aggressive increases in production of farmed salmon resulted in a collapse in prices, for which Norway was widely blamed. The industry responded with a major effort to reduce the cost of production. The early 1990s saw huge improvements in feed formulation and manufacture, the use of vaccines to control disease, and the design of equipment to reduce labor costs on farms. By 2000, the cost of production on most farms was less than half the level in the late 1980s when the first market crisis began.

Since then, the global industry has been through various market perturbations with the price rise in 2009 and 2010 being triggered by increased demand and disease problems in Chile which reduced global supplies (see Figure 11).[36] The recent fall in prices results from slack demand and Chile returning to the market Alarmingly for prices, Bloomberg reports that Chile's production is pegged at 300,000 tons of farmed Atlantic salmon by 2013, nearly triple 2011 output - and almost as high as Alaska's total annual salmon harvest.[37]

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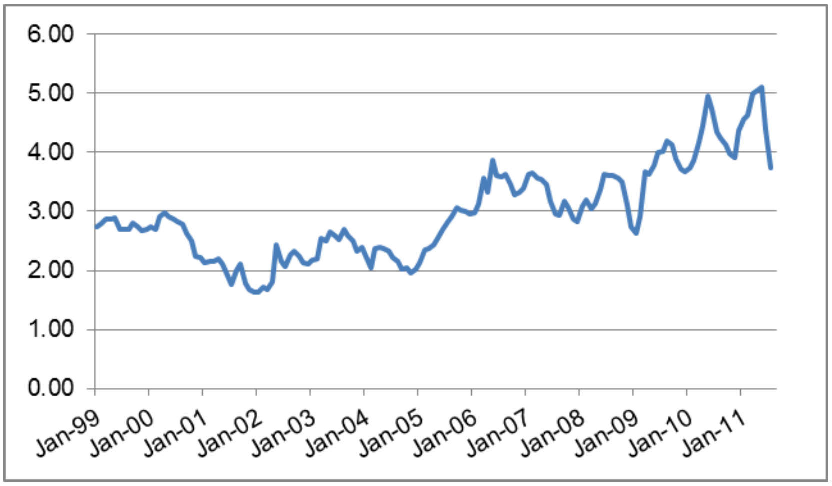
[36] Urner Barry's Fresh Farmed Salmon Index is an indication of the combined average value for Chilean fillets, European fillets, Northeast wholefish, European wholefish, and West Coast wholefish. It is a weighted value of each commodity as a proportion of the total supply from the producing areas. For example, if Chilean fillets represent 60% of the total, West Coast wholefish 25% and North Atlantic wholefish 15%, the value of each commodity would be weighted accordingly. This index is intended to be viewed as a snapshot of the general health of the fresh farmed salmon market in the United States.

[37] Seafood News, August 3, 2011.

Figure 11: Urner Barry's US Fresh Farmed Salmon Index ($/lb)



Source: Urner Barry Comtell

The US is not one of the major players in farmed salmon production. Its total annual production fluctuates between 10,000 and 20,000 metric tons, or from 0.6% to 1.2% of the current world production (1.8 million metric tons of all salmonids are farmed in salt water – this includes sea trout and coho salmon in Chile). Yet the US is a large market for salmon and is a major importer of product to supplement its wild harvested supplies. In 2009 the US imported 285,000 metric tons of farmed salmon[38] [39] mostly from Chile and Canada; over 17 times more than it produced.

The primary reason that US salmon farmers have not been able to keep pace with developments in their home market is lack of access to suitable farming (net pen) sites. Apart from Alaska, Maine, and Washington there is little, if any, coastline that provides the right conditions for farming salmon using conventional net pen production methods. In Alaska, which has a suitable coastline and many potential sites, fish farming in floating cages has been banned.

In Maine and Washington, suitable coastline is more restricted than in Alaska and competition for space for other commercial and recreational uses is intense. This conflict of use has resulted in intense opposition to the further development of the industry in these states, leading to the development of a restrictive regulatory framework. Thus, the potential to expand and compete with imports, even with relatively high prices in the past two years, is restricted (see Section 2.2.1).

Despite the challenges of the last three decades, the global farmed salmon industry has been extraordinarily successful. They have increased production globally by over 200 times in just 30 years, and improvements in productivity have made the product affordable to many more consumers. Modern salmon farming pioneered a novel method of seafood production. In so doing, it developed techniques that have already been applied to the production of other fish species and will be applied to more in the future. It has demonstrated that the farming of coastal waters can produce good quality fish at a price that meets

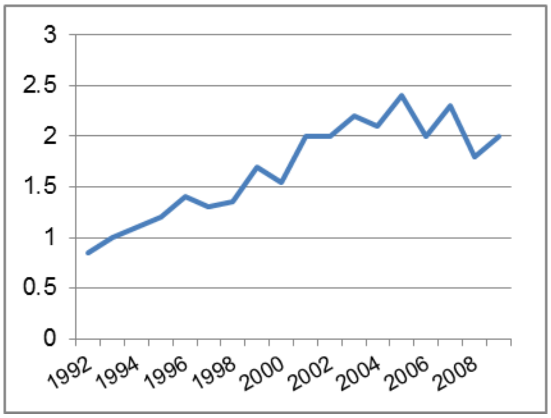
[38] This weight is calculated from imports of fresh and frozen whole gutted fish of 206,000 lbs and of fillets of 220,000 lbs converted back to live weight assuming 90% and 55% recoveries respectively.
[39] http://www.ers.usda.gov/Data/Aquaculture/SalmonImportsVolume.htm

the value expectations of a mass market. Its development has been an outstanding technical and marketing achievement that points the way to farming more aquatic animals to meet growing demand for animal protein. Previously a luxury item, farmed Atlantic salmon is now a leading seafood commodity.

Consumption

The National Fisheries Institute has been able to estimate the US consumption of salmon products since 1992. Consumption per capita doubled from 1 pound per person in 1992 to 2 pounds in 2000. Since then it has fluctuated around that level (see Figure 12).

Figure 12: US consumption of salmon (lbs/head)



Source: Urner Barry

Knapp et al identified the proportion of different species of salmon consumed in 2004, the last time these data were published.[40] There are five species of Pacific salmon plus Atlantic salmon. Of the 284,000 metric tons that Americans consumed on average over the years 2000 to 2004, 105,000 metric tons (37%) was Pacific and 180,000 metric tons (63%) was Atlantic salmon. Almost all of the Pacific salmon was wild caught (93%), while 99% of the Atlantic salmon was farm raised. Since almost all the Pacific salmon is wild caught, roughly 1/3 of salmon consumed in the US was wild and the remaining 2/3s was farm raised.

Of the 180,000 metric tons of Atlantic salmon sold in 2004, 156,000 metric tons was sold fresh. The remainder was sold frozen. In contrast, only 22,000 metric tons of Pacific salmon was sold fresh, and almost all was chinook and sockeye salmon. Of the remainder, 36,000 metric tons was sold frozen and 47,000 metric tons was sold canned. The majority of the canned is pink and the majority of the frozen is chum salmon. Overall, Pacific salmon accounted for 100% of canned consumption, 60% of frozen consumption and only 12% of fresh consumption.

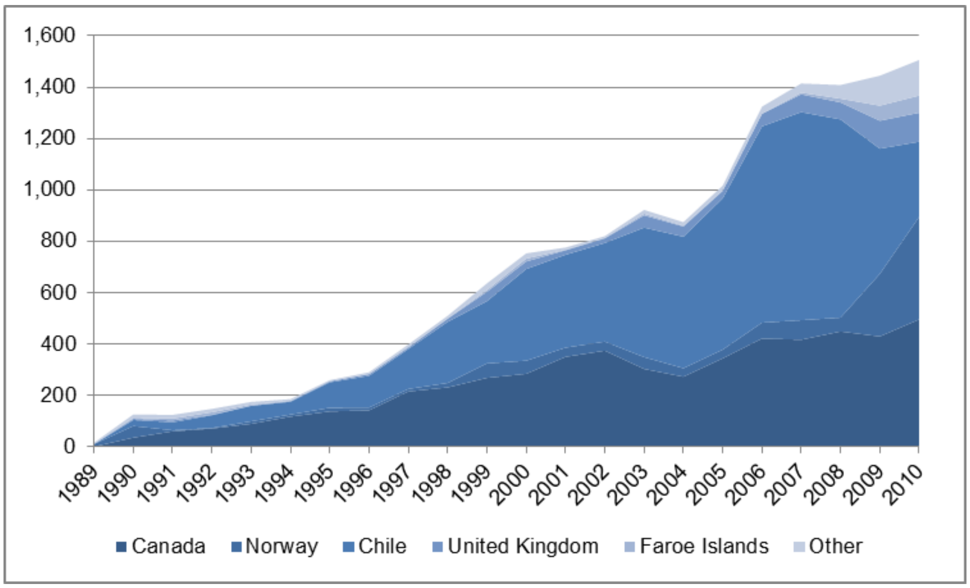
[40] Knapp G, et al, The great salmon run: competition between wild and farmed salmon, TRAFFIC North America, World Wildlife Fund, January 2007

Imports

In 2009, the US imported 285,000 metric tons of Atlantic salmon calculated on a live-weight basis with a value of $1.439 billion[41]. Canada, Norway and Chile were the leading suppliers with exports of $495, $400, and $293 million respectively. From 2000 to 2009, Chile exported more salmon to the US than everyone else, according to ERS data. In 2007, Chile exported $810 million (231 million pounds) worth of salmon, which is more than all of the other imports combined. However, in 2007 Chile was devastated by an outbreak of ISA, which resulted in losses of more than 50%. Figure 13 below shows the impact on US imports. Chile is believed to have only temporarily lost its number one position, falling below Canada and Norway. Chilean exports are expected to recover as the Chilean industry adjusts its production methods to reduce the risk of more serious disease outbreaks.

In very broad terms we estimate in 2010 that US farmed product had roughly a 5-7% share of the US salmon market when expressed in live equivalents, with imports representing 68% and the remainder being met by wild harvested US supplies.

Figure 13: US imports of Atlantic salmon, by country, in million dollars



Source: USDA, Economic Research Service

5.2.2 Output (volume and value)

US annual production of farmed salmon fluctuates between 10,000-20,000 metric tons, 0.6% to 1.2% of the world production.

- The estimated annual production for Maine in 2010 is 27 million pounds. Production has varied considerably, reaching a peak of 35 million pounds prior to infectious salmon anemia (ISA), and dipping to 8 million pounds in 2007. The value is dependent on the market; however 2010 prices were elevated because of shortages caused by disease problems in Chile. The value is estimated at $76.8 million.

[41] http://www.ers.usda.gov/Data/Aquaculture/SalmonImportsValue.htm

- Washington's Department of Fish and Wildlife does not keep data on value. However, the average unit value is comparable to Maine ($2.84/lb) and based on the 2010 harvest, farmed salmon in Washington was worth $52 million.

5.2.3 Number of producers and regional distribution

There is one producer of Atlantic salmon in Maine and one in Washington. Section 5.2.4 gives more details on these two companies. In 1998, the Census of Aquaculture recorded 28 farms producing salmon in the contiguous 48 states (some of these may have been hatcheries for wild population enhancement) and the 2005 census identified 12 farms (8 in Maine, 3 in Washington, and 1 in Tennessee, the latter probably a hatchery). The US lacks suitable farming sites in other states, with the exception of Alaska where floating cages are prohibited. It should be noted that there is one small producer of coho salmon at an inland site, and at least two companies are exploring production of Atlantic salmon in freshwater (possibly) at inland sites.

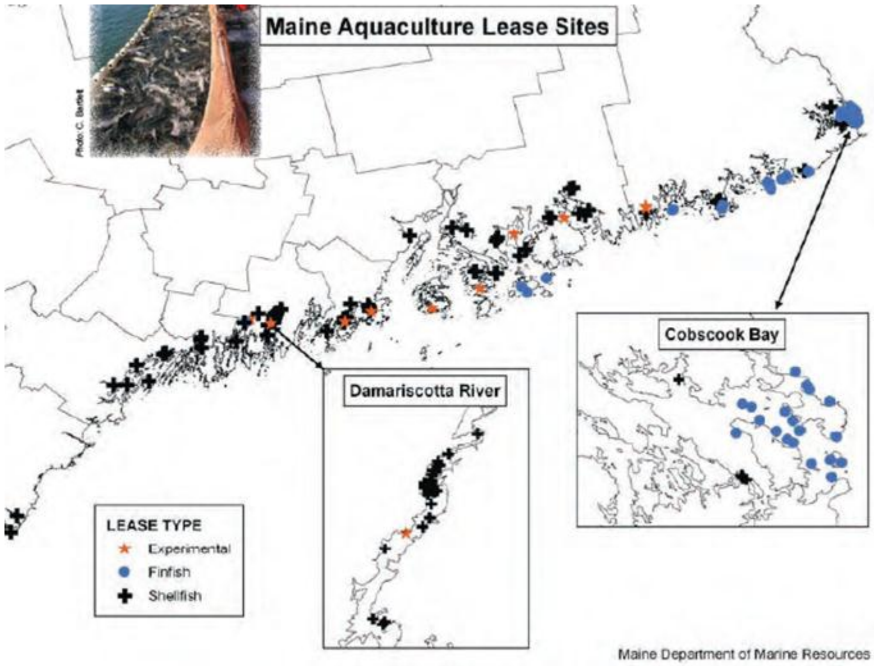
Maine

Figure 14 is a map published by the Maine Department of Marine Resources to show aquaculture leases in the state and shows how salmon farm leases are concentrated in the north in Cobscook Bay. According to Maine's Department of Marine Resources, as of March 3, 2011 there were 26 finfish leases (620 acres total) located in marine and estuarine waters along the Maine coast of which 16 are in Cobscook Bay.[42]

Rent is charged at the rate of $100 per acre per year. The acreage allows space for the floating cages and, more importantly, for the mooring systems that extend well beyond the cage footprint at the surface. Therefore, the acreage leased is based on the seabed area and it is estimated that the cages at the surface occupy only roughly 11% of the seabed area leased.

[42] http://www.maine.gov/dmr/aquaculture/leaseinventory/index.htm

Figure 14: Aquaculture leases in Maine



Source: http://www.maine.gov/dmr/aquaculture/documents/brochure.pdf

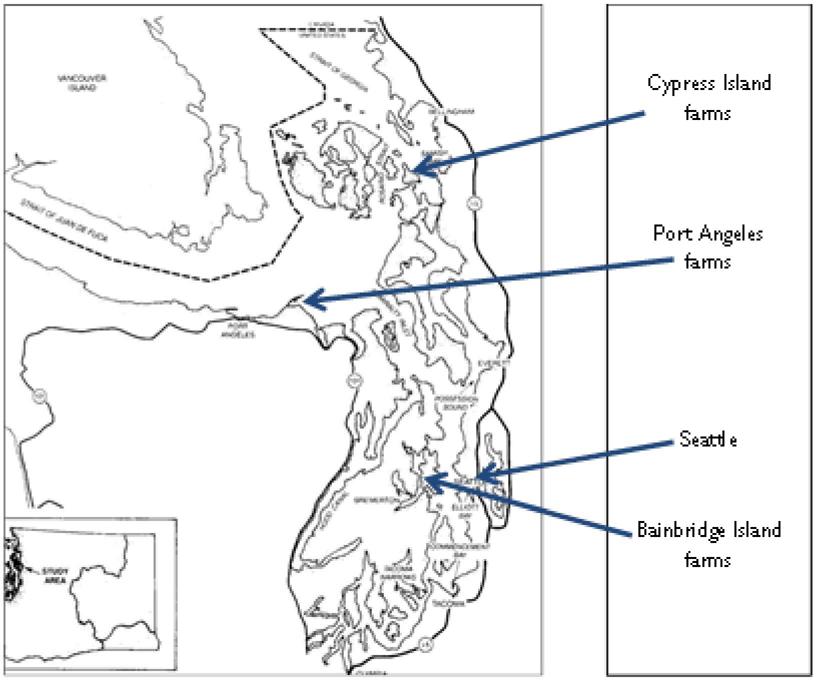
Washington

Figure 15 shows a map of Puget Sound, Washington, with the location of the present commercial salmon farming facilities marked. These leases have not changed since the early 1990s, there being nine separate net pen structures that are contained within four lease areas.

The sites are leased by the Washington Department of Natural Resources and rent is charged at a $15,000 per year flat rate plus a volume/price based royalty. The total seabed area of the active leases is 180 acres and the estimated acreage of the cages on them is 18 acres.[43]

[43] Kevin Bright, Environmental Permit Coordinator, American Gold Seafoods, personal communication.

Figure 15: Salmon aquaculture leases in Washington



5.2.4 Concentration of ownership

Through successive waves of industry consolidation smaller companies have been taken over by larger players. Economies of scale, the need for scale to be able to respond to the demands of the modern marketplace, and access to capital to update equipment and to withstand market cycles have all been factors at work. The result is a US salmon farming industry that is now owned by just two companies, one in Maine and one in Washington, both of them with production facilities in the other major producing countries, and both exporters of farmed salmon to the US. On a global level it was estimated in 2001 that the world's 30 largest salmon farming companies produced 71% of the world's total farmed salmon production.[44] More recently, one company, Marine Harvest, in 2009 produced 307,000 metric tons, which was 20% of the global production of 1.54 million metric tons of Atlantic salmon.[45]

- **Maine:** In 2003, three international salmon farming companies owned or subcontracted almost all the salmon farming capacity in Maine. They were Stolt Sea Farm Inc, Atlantic Salmon of Maine and Connors Aquaculture, which was part of the Heritage (George Weston) group. Today all the farms are owned by just one company, Cooke Aquaculture Inc, which had developed a successful salmon farming business in New Brunswick and took the opportunity to acquire assets in Maine as they became available. Cooke Aquaculture also owns and operates hatcheries in Maine to provide their cage farms with smolts.

44 Korneliussen, Pal., 2001. The world's 30 largest salmon farmers. Intrafish (www.intrafish.com). The author projected that these companies would produce 920,000 mt in 2001. Total world production that year is reported at 1.3 million mt. Therefore, the 30 companies would produce 71% of the total.

45 Salmon Farming Industry Handbook 2010. www.marineharvest.com/PageFiles/1296/Handbook%202010.pdf

- **Washington:** In Washington the ownership history has been turbulent. In 2003, the farms were owned by a company known as Pan Fish ASA, a Norwegian company that is no longer in business. Pan Fish was sold to a private Washington investor who renamed the company American Gold Seafoods. In 2008, the investor sold American Gold Seafoods to Icicle Seafoods Inc., which is owned by a US investment company, Paine and Partners.[46] The Washington salmon farms continue to be owned and operated by one company.

5.2.5 Markets

Fifteen years ago salmon farmed in Maine and Washington was sold mostly through traditional seafood distributors and wholesalers. This remains an important market channel. For example, it is always available at the Fulton Market and the New York Fulton Market price is one of the indexes the industry uses to gauge market movements. However, because it is farmed and the supply is therefore predictable, traditional seafood marketing processes that have evolved to deal with the complexities and vagaries of the supply of wild caught fish are less relevant. Obviously, distribution is still vital, but sourcing, which in many respects is the critical component of traditional seafood wholesaling, is much less of an issue.

As farmed salmon has become a mainstream, everyday seafood item in supermarkets and club stores throughout the nation, salmon farmers have to reach very large buyers. For example, in 2002, Costco is reported to have sold 600,000 pounds of fresh salmon fillets a week, corresponding to an annual live weight (unprocessed) volume of about 25,000 mt per year. The demands of large buyers such as this have been a key factor in the consolidation of ownership of farmed salmon and make it virtually impossible for small producers to operate except in small, usually local, market niches. Demands by big buyers for assurance on quality and traceability and for year-round availability of large volumes, all to be provided at highly competitive prices, mean that only large companies can operate in such a market. More salmon is now sold also as part of long-term supply agreements with food service and retail buyers. The reality is that bigger companies are better able to survive price downturns than small ones. Consequently, had they not had the benefit of corporate capital, management and market strength, the salmon farming industries in Maine and Washington might have been driven to extinction by now under a rising tide of imports from much larger overseas competitors.

Contracts with major buyers offer some security to salmon farmers, although it is unlikely that many of these are on fixed prices. However, salmon producers and buyers now have another tool to deal with price risks through an independent salmon futures trading entity operated by 'Fish Pool' in Norway.[47] Fish Pool ASA is licensed as a seafood commodity derivatives market by the Norwegian Ministry of Finance under the surveillance of the Financial Supervisory Authority of Norway (Kredittilsynet). This independent surveillance ensures the integrity of the market. However, use of the market is still relatively limited and is probably limited to the Norway trade as the contract is traded in Norwegian kroner and exposes users from other countries to currency risk. Contract volumes traded in the first half of 2011 reached 74,600 tons, a relatively small proportion of the Norwegian output, although almost twice the volume traded in the first half of 2010.

[46] http://fis.com/fis/techno/newtechno.asp?id=41729&l=e&ndb=1
[47] http://fishpool.eu/index.aspx

Farmed salmon is a commodity and regional prices reflect fairly accurately the spot price in regions where there are major sellers, notably Norway. Salmon farmers and marketers have little or no pricing power and the market price moves up and down in response to day-to-day supply and demand pressure. Salmon farming companies have tried to respond to this in different ways over the years, none of them very successfully. Approaches that have been or are used include:

- To try to read annual trends in prices and have fish ready when prices are highest. This is difficult to do given other production and market variables and with a product that takes two to three years to grow to market size. But since the market will accept quite a wide range of fish sizes, they are sold in a number of weight ranges (measured as head-on, gutted weight in pounds (lbs)) i.e., 6 to 8s, 8 to 10s, 10 to 12s, etc. Weights between 6 pounds and 12 pounds are the most common, but at certain times of the year farmers will produce some 4 to 6s and fish larger than 12 pounds and up to 20 pounds.
- Development of brands. An expensive option that demands substantial resources and is difficult unless the raw material is further processed in some way.
- Development of value-added products that are differentiated from the commodity. This may provide short term advantage, although competitors can quickly copy any innovation and the costs of value adding limit pricing flexibility, though they do expand the range of potential buyers and, therefore, increase overall demand.
- Generic marketing to increase demand. A successful program was initiated under the auspices of the International Salmon Farmers Association some years ago, but was undermined by a trade action against Chilean salmon farmers who then withdrew their support and with it much of the funding.

5.2.6 Price data

There is weekly price data available in two places for farm-raised salmon.

- The Fulton Market and the New York Fulton Market price is one of the indexes the industry uses to gauge the market movement of Atlantic farm raised salmon.
- Urner Barry Seafood Current is published twice weekly and includes data on farm-raised, fresh salmon from the West Coast. Urner Barry's Fresh Farmed Salmon Index is also used to get a general flavor of the market situation (see Footnote 36). .

5.2.7 Availability of production history and other data

There are no data that describe variations in individual US salmon farm performance. Clearly, with only two companies, no detailed performance data will be made available unless by the companies themselves. Salmon production history will be well studied in the leading salmon production countries in support of widely used insurance policies.

There are very broad descriptions of the industry character in Maine and Washington. Maine Department of Agriculture has value and volume production data available for the state since 1991. The Washington

Department of Fish and Wildlife maintains the production volume data for the state of Washington. They do not have recorded value data.

Production costs

Costs in the salmon farming business are typically apportioned as shown in Table 9, the cost estimates provided being an approximate generic estimate for general guidance only.[48] These data are based on Norwegian costs. As such, they are some of the most competitive in the world. US costs will be slightly higher, but are likely to be similarly constructed.

Table 9: Estimate of the average farming costs to grow salmon in 2009 [24]

Cost item	$ per kg Salmon grown	% of total costs
Feed	1.31	55.7
Smolts	0.33	14.0
Operations, R&M, Insurance	0.30	12.8
Wages	0.25	10.6
Depreciation	0.16	6.8
TOTAL	2.35	100.0

Note: in this table Operations, Repairs & Maintenance and Insurance are separated from Depreciation, while Financing Costs are excluded. In the Norwegian data from which it was derived, all these costs, including a financing cost are included under 'Other & Financial'.

Feed

Feed is the largest expense on a salmon farm comprising 50% to 60% of total costs on most efficiently run farms. Because the raw ingredients in salmon feed, such as fishmeal, are globally traded commodities priced in US dollars, feed prices tend to be in a similar range for all farmers, plus or minus costs for freight and any short-term exchange rate advantages. Chile has the lowest cost feeds because fishmeal is produced there and requires little shipping, although many farms are substituting plant and other proteins as fishmeal costs are now so high. Lower labor costs in Chile also help in feed manufacture. The world price of fishmeal, which is the most important ingredient in present day feeds, is governed by usual supply and demand criteria, but is also influenced by availability and price of other commodity proteins such as soybean meal. Salmon farmers are working to reduce the levels of both fishmeal and fish oil in feeds also in response to concerns about the ecological impacts of the fisheries that produce them.

Improvements in feed formulation and manufacture have led to increasing feed efficiency in recent years. Modern salmon feeds are now made using a cooking extrusion process which produces pellets that can absorb and hold much higher levels of fat (fish and vegetable oils) than was previously possible. It has been found that high levels of fat increase feed palatability and lead to more efficient utilization of protein - the most expensive component of the feed. This means that an efficiently run salmon farm, with the fish in good health, should now expect feed conversion rates of 1.3:1 or better.

[48]Forster, J, 2010. What Can US Open Ocean Aquaculture Learn From Salmon Farming? J. Mar. Tech. Soc. Vol. 44, No.3 pp68 - 79

Smolts

Several years ago there was an open market for smolts that were produced by private hatcheries. Prices ranged between $1.50 and $4.00 each depending on availability, size, and quality. These prices have tended to come down as the industry has developed. Industry consolidation has meant that most smolts are now produced 'in house' in company-owned hatcheries, so how they are costed into the overall production process is not so transparent. Industry participants usually suggest that a cost today of between $1 and $1.25 each delivered to the cages is a reasonable figure to work with, though this may be higher for smolts whose growth has been accelerated by warm temperature rearing, or for fish that are held in tanks on land after smolting and are transferred to the sea later. The costs include feed, operations, R&M and insurance, wages and depreciation, as in Table 2, as well as the cost of vaccines for vaccinating the fish prior to their transfer to salt water. The cost of vaccination is around $0.12 per fish for a multi-valent vaccine that protects against several threatening bacterial diseases including furunculosis and vibrio.

Smolts represent a significant part of the cost of producing the finished fish; just how significant depends on survival and the final size at which the fish is harvested. For example, if a $1.25 smolt is grown to a salmon of 10 pounds dressed weight, with 90% survival, its cost on a unit weight basis is $0.14 per pound of fish produced. Survival and harvest weight are obviously key factors in determining actual smolt costs for different farms.

Operations, repairs and maintenance, and insurance

These are all the costs associated with the logistic support and maintenance of a farm such as fuel, supplies, repairs and maintenance, fish health management and environmental monitoring. Compared to farms in more remote parts of the world, those in Maine and Washington have access to excellent supporting infrastructure, so in this respect they have a small competitive advantage.

Insurance against fish mortality from disease and other factors has become increasingly expensive and difficult to obtain in the last few years. This is due to a poor loss record by salmon farms and a prolonged learning curve by the insurance industry. The causes of losses on fish farms can be region or even site specific. As the commercial fish stock mortality market has changed, larger salmon farming companies also have the possibility of providing for some of their own insurance cover through self-insurance and 'captive' insurance arrangements[49], so it makes it difficult to pin down a total cost. In general, a premium rate between 3% and 5% of the insured value is probably what it costs most companies, depending on individual loss records and the specific terms of the policy.

The insured value is the value declared at the end of each month. Therefore it is the value of the stock in the farm at any one point in time. Premiums are adjusted annually based on the average of 12 monthly declared values. The declared value is calculated by setting values to different sizes of fish, e.g. $2 each for newly entered smolts, or $7/kg for fish in the 1-2kg size range and applying these to the inventory each month. This is the value on which indemnity payments are calculated should there be a loss.

[49] Captive insurance is, in effect, self-insurance, where a company assumes the risks of loss internally. However, it is possible to set this up in a 'captive arrangement' whereby notional insurance premiums are paid into a special captive account and as such are protected from tax.

An important point here is that the US salmon industry has access to private insurance. The Atlantic salmon industry is one of the prime targets for private aquaculture insurance and as production systems are similar, insurers can use international experience as a proxy for the US. Also, the US industry is small and relatively easily accommodated by the large insurance companies through a small number of brokers.

Costs for health management comprise various activities associated with preventive care and such medications as may be necessary. The use of vaccines has led to a marked reduction in the use of medications in recent years. In Norway for example, antibiotic use on salmon farms has been cut dramatically since the 1990s primarily due to the efficacy of modern vaccines.

Other costs of health management include any specific sampling and screening that may be required, especially for broodstock, and management protocols that may be employed as part of a preventive care strategy. The latter is particularly important in Maine currently, where ISA was a serious problem in 2001. This required the implementation of rigorous biosecurity procedures, including vigorous hygiene and disinfection procedures for equipment, processing waste and personnel, as well as the implementation of Area (Bay) Management Agreements. These measures are described in detail by APHIS (2010)

Labor

Labor is used in salmon farming for farm operations, logistic support, and management. Specific tasks on the farms include:

- Smolt delivery, which only happens a few times per year but must be done with skill and speed to avoid causing stress to the young fish.
- Feed distribution, which is mostly mechanized and computer controlled now.
- Recovery of any fish that die ('morts') and inspection of nets and mooring systems, which mostly require diving.
- Harvesting, this is usually done using a work boat equipped with fish pump or brail, which load the fish into a live well on the boat or into totes.
- Machinery maintenance and repair.

All of these tasks require skill in the use of equipment, sensitivity in the handling of live fish and care in the practice of sanitary procedures. Therefore, salmon farm workers and operators are often college educated and have a strong sense of professional responsibility. Utilization of labor has improved markedly over the years in response to mechanization and increased scale. Normal productivity levels on salmon farms today range from 500,000 lbs. to one million lbs. per person-year. At an average wage rate, including benefits, of $45,000 per year, this means the farm labor cost component to produce salmon is between $0.09 per lb and $0.18 per lb.

Depreciation

Depreciation charges can vary widely depending on the age of the assets, the depreciation rate used and the cost of the initial equipment. Salmon farm equipment tends to deteriorate quite quickly due to the harsh environment in which it operates. Also, the technology and design of equipment is evolving quickly so it can become obsolescent quite rapidly. The result is that depreciation is a significant cost of salmon production.

5.2.8 Biology

Wild Atlantic salmon are native to the North Atlantic. Today they are only rarely found in the wild. After spawning they move to feeding grounds in the ocean, feeding on pelagic species such as herring, sprat and squid. After four years they return to their rivers of origin to spawn (October-January). Few return to the sea after spawning. The hatched fry ('alevins') and juveniles remain in freshwater, feeding from insect larvae and smaller fish. A change in day length (photoperiod) triggers smoltification and the 'smolts' migrate through rivers to the sea.

The process of domestication in temperate climates with shelter, and stable temperatures and salinities, took place within latitudes 40-70º in the Northern Hemisphere, and 40-50º in the Southern Hemisphere. Today, the breeding of intra-specific hybrid strains has greatly enhanced productivity and domestication. Year-round spawning is induced by artificial lighting. Atlantic salmon grow best in sites where water temperature extremes are in the range 6-16 °C, and salinities are close to oceanic levels (33-34 parts per thousand).

5.2.9 Production system

Production approaches

A primary thrust in the development of salmon farming was the premise that consumers prefer fresh rather than frozen fish and that by farming them, rather than catching them in seasonal fisheries, farmers could satisfy this preference.

Today, year-round supply is a key assumption in all of the salmon farming companies' marketing programs and this has been a driving force in how production is planned. Consistent, year-round production also allows processing plants to be operated more efficiently, which has become increasingly important as the industry has responded to market demand for more further-processed products, such as fillets and portions.

However, year-round production of fish of the same size is not easy to achieve because of the natural growth and breeding cycle of salmon. They spawn on a seasonal basis only, with eggs usually being taken in the late fall, though this can be manipulated by using artificial light regimes if needed. Growth of salmon also varies with water temperature, growth being faster at summer temperatures up to about 16° C. During the winter, growth slows, especially in Maine.

Salmon farmers have responded to and dealt with these difficulties in several ways:

- First, since the market will accept quite a wide range of fish sizes, they are sold in a number of weight ranges (measured as head-on, gutted weight in pounds (lbs)) i.e., 6 to 8s, 8 to 10s, 10 to 12s, etc. Weights between 6 pounds and 12 pounds are the most common, but at certain times of the year farmers will produce some 4 to 6's and fish larger than 12 pounds and up to 20 pounds.
- Second, because fish within a population grow at different rates, it is possible to sort faster growing fish from slower growing fish by grading, although that farmers are reluctant to do

this too often because it is stressful to the fish. Therefore, to some extent, the natural growth variation between fish can be used to spread the availability of fish within the preferred size range.

- Third, advances in hatchery methods that enable water temperature to be controlled at reasonable cost, have meant that juvenile fish can be brought to the smolt stage at different times of the year instead of only in the spring as was the case in the past. Smolts can be entered into seawater over a wider period of time allowing sequencing of different batches of fish. Some salmon farmers, notably in Norway, are experimenting with growing the smolts for some months beyond the freshwater stage in land-based tank systems through which seawater is pumped and/or recirculated. Though this is more costly than growing them in cages, it also reduces some of the risks inherent in cage production, and it is feasible because the fish are still fairly small and do not occupy a lot of space. It may take several years yet before the balance of advantage in doing this is fully understood, but it is a model that could apply to all marine species and, therefore, represents a potentially important innovation.

Culture stages and practices

The salmon farming process is managed in three stages. They are:

- Broodstock for the production of eggs.
- Hatcheries where eggs are incubated and hatched and where the young fish are raised until they are ready to go to saltwater as 'smolts' or, as in the recent trend noted earlier, as partly grown smolts that have spent another few months in tanks on land.
- Net pens where the smolts are acclimatized to saltwater and grown out to market size.

Broodstock are usually maintained and selected as part of specialized breeding programs. They are fish that have performed well under farm conditions and are in good health. To reduce the risk of exposure to pathogens they are isolated from other 'production fish' early in the rearing process and held in separate facilities. As an anadromous fish, Atlantic salmon brood fish can even be held in freshwater for their whole life cycle, which protects them from exposure to disease in marine waters but eliminates the selective pressure that this part of the process imposes.

Atlantic salmon usually become sexually mature between three and four years of age and become ready to spawn in the late fall. However, natural spawning does not occur under farm conditions so eggs and sperm (milt) are taken from the fish by farm personnel by a process known as 'stripping'. The eggs and milt are then mixed together with a little water to allow fertilization. Fertilized eggs are then disinfected with an iodine-based solution and placed in incubators in a hatchery to develop.

Each female salmon will produce between nine and fourteen thousand eggs. The batches of eggs from each female are usually incubated separately. This is because tissue samples from the mother are taken at the time of egg stripping and screened for viral and bacterial pathogens. If pathogens are found in any of the samples the eggs from that particular female are discarded.

The speed at which the eggs develop and hatch is governed by water temperature. This is sometimes manipulated in the hatchery to delay or accelerate the hatching process. When the eggs hatch, the young fish are called 'alevins' or 'yolk-sac fry'. At this stage they do not move much, preferring to hide among crevices provided by special media placed in the rearing tanks. They continue to develop and grow while the yolk sac that provides them with nutrients is absorbed.

When the yolk sac is absorbed the young fish or 'fry' begin to swim and look for food. They are then fed with a very fine particulate feed in a process known as 'first feeding'. Because the fry grow quite slowly at this stage the rearing water is often heated in order to increase growth rate. It is worth noting that salmon (and trout) are one of the few farmed fish whose newly hatched fry will take dry feed at first feeding. Mostly, newly hatched fish are smaller and require live feed for several days or weeks before being weaned on to dry pelleted feeds.

For the next nine months to a year the fry continue to grow in hatchery tanks until they become 'smolts' at a weight of between 80 and 120 grams. The process of 'smoltification' prepares the young fish for transfer to salt water and involves changes in their osmoregulatory systems and appearance as they become more silvery in color and elongate to become longer and leaner. Smoltification' is induced by changes in day length to which the fish respond so that under normal conditions they are ready to go to sea in the spring. However, smoltification can also be controlled in a hatchery by manipulating day length through the use of artificial lighting. Its importance is discussed further under Section 5.2.10.

A few weeks before they become smolts, the young salmon are vaccinated to protect them against pathogens to which they will be exposed in salt water. Vaccination can be done by dipping the fish in a vaccine solution, but most commonly is done by injection. This requires the fish to be anaesthetized and then individually injected with a vaccine dose. Though laborious and stressful on the fish, this vaccination procedure has been found to be highly effective against certain bacterial pathogens, notably against bacterial diseases such as vibrio and furunculosis.

When smolts are judged to be ready to go to seawater they are transported by tanker truck, or in live wells on a boat, to net pens in sea. Once in the net pens the process of adaptation to saltwater occurs quickly and they begin to feed within a day or so.

Then begins the process of 'on-growing' when, for the next 15 to 24 months, the fish are fed and cared for as they grow to market size. During this time they will sometimes be graded for size, moved and spread out into other nets so they do not become too crowded. Harvesting occurs when the fish are judged to be big enough for sale or when market demand requires that fish be made available. It was noted previously that demand for farmed salmon is now year round. Salmon farmers must meet this demand if they are not to lose out to their competitors. Since the growing cycle still has elements of seasonality both with respect to the life cycle of the salmon itself and to seawater temperature, perfect year-round availability is still difficult to achieve.

Harvesting requires the fish to be netted or pumped from the net pens and taken to a processing plant. This is done in several ways, the simplest being when salmon can be live hauled in a well boat or special transport cage to a nearby onshore plant. Since plants are not always available in the locality, the alternative is to stun and bleed the fish at the farms and then take them by road to the plants in containers packed with ice.

Production facilities

Though they are quite different in design and purpose, hatcheries and net pens are both 'flowing water' methods of fish farming. This means that a constant flow of clean water must pass through tanks or net pens in which the fish are held in order to replenish dissolved oxygen and to remove fish waste. This is quite different from 'pond' methods of fish farming, such as those found in the catfish industry, where there is little or no water exchange. In a catfish pond, natural processes within the pond itself assimilate fish wastes and much of the oxygen that the fish require is provided by natural gaseous exchange at the water surface, by photosynthesis from algae in the pond water, or mechanical aeration techniques.

The requirement for a constant flow of water in salmon farming is the primary factor in deciding where salmon hatcheries and farms can be located and how they are operated. In the case of hatcheries the flow is managed 'actively;' that is to say, that water is drawn from a well or diverted from a spring or stream and piped to the rearing tanks where a valve controls the water flow. Increasingly today, also, it is recycled using recirculating systems where the water is filtered to remove fish wastes, re-oxygenated to meet the fishes' oxygen requirements and often heated to optimize fish growth (see RAS Section 3.3).

In net pens water flow is 'passive,' as it is entirely dependent on natural water currents in the area that are driven by winds and tides. A net pen farmer can do little to manage this flow other than to select a location where good flows occur and then keep nets clean so that water can pass through the meshes freely.

Hatcheries

There are several different ways that a hatchery can be laid out and designed. Because hatcheries produce small fish the containers (tanks) in which the fish are grown are always a great deal smaller than net pens used for on growing. Hatchery tanks will usually range in size from 10' to 30' in diameter and be two to three feet deep. Where RAS technology is used, facilities are normally indoors.

As noted above, water flow is the critical element in keeping the fish healthy and alive. For this reason hatcheries are usually equipped with alarm and back-up systems to warn of and deal with a failure in the water supply. Where pumps are used, back-up power generation is also essential, as is effective training of staff to be able to respond to emergencies when they do occur.

An especially effective back-up system that has become widely used in recent years is an on-site supply of liquid oxygen or a store of pressurized oxygen. Oxygen is often used routinely in hatcheries today to increase dissolved oxygen levels in the water supply to rearing tanks, thereby increasing its 'carrying capacity,' meaning that less water has to be used. But it also provides an emergency life support system because oxygen gas can be bubbled into fish tanks to maintain dissolved oxygen levels and keep fish alive on a temporary basis while a mechanical failure elsewhere is fixed. Since oxygen can be stored in large quantities as a liquid and requires no external power source to vaporize into a pressurized gas, its supply is completely independent of all other hatchery mechanical and electrical systems, making it a very reliable back-up resource.

Net pens

A net pen consists of a floating collar from which a net bag is hung and, through weights attached to the bottom of the net, the bag is shaped to provide a rearing container for the fish. Collars are usually made from steel or PEH (plastic) pipe with floatation provided by fixing special floats under the steel beams or by sealing air into the pipe. They are usually square or circular and set in groups of as many as 24 in one location, depending on individual pen size and location. Net pen collars used on salmon farms today usually have a surface area of between 2,000 and 10,000 square feet.

Nets are mostly made from nylon with smolts being put into nets with smaller mesh than is used when the fish are larger. Nets are built with various ropes and rigging lines to enable them to support weights, to keep their shape, and to provide strength. Net depth depends on the water depth at the farming site and farmers usually try to provide for at least as much depth under the net as the net is deep. This allows for waste dispersal. Net depths range from as little as 20' up to 60' at particularly deep sites.

There is little that is conceptually complex about net pens. They are net bags floated and rigged in such a way that they will hold fish, and located so the natural forces of wind and tide provide a flow of water through the meshes. As with many simple concepts, however, the devil is in the details. The last 40 years, during which the salmon farming business has developed, have seen enormous improvements in net pen design and construction. With these improvements have also come developments in mechanical handling, so that sophisticated automatic feeding systems and specially equipped service boats today service most salmon farms. Underwater cameras and sensors can also be used to monitor conditions. These developments have allowed the industry to reduce costs, which, in turn, has allowed its products to become increasingly affordable to a mass market.

A critical part of a net pen system is the part that is rarely seen, namely, the mooring system. This is a system of anchors and lines installed to hold a group of circular salmon cages in place. The type of anchors used depends on the nature of the seabed at the site and often on what is most readily available locally. There are many ways in which a mooring system can be configured, but its critical function is to hold the cages in place and, especially, to be able to do this during extremes of weather or tide. Maintenance and inspection of mooring systems is as important as the design itself; accidents have occurred in past years when deteriorating system components were not noticed until too late.

5.2.10 Length of production cycle

In general the grow-out phase takes between 15 and 24 months. Timing of the cycle and inputs are driven by seasonal changes in water temperature and day length, and by the need to try and maintain year round production. There are important differences in water temperature between Maine and Washington. In Maine both freshwater and seawater temperatures are more extreme, especially during winter when lows near freezing are not uncommon, and when salmon growth slows to almost nothing. In Washington, the seawater temperature rarely falls below seven degrees centigrade, at which salmon grow quite well. This means that farmers in Washington find it easier to maintain year-round production because growth is sustained throughout the year. They are helped further in this now by being able to produce and stock smolts at different times of the year, using artificial lighting.

Regardless of when they are stocked, most salmon farms today operate on what is called an 'all in all out' basis, or single year class stocking followed by a period of weeks or months 'fallowing' when no fish are in the farm after harvesting. This is done to interrupt disease and parasite cycles, a practice that is made more effective when farmers within an area coordinate production cycles between them in what are known as Area (or Bay) Management Agreements. This practice was embraced in Maine first following an outbreak of the disease Infectious Salmon Anemia (ISA) in 2000 - see Maine below. Farms in Washington are being converted to it now and it is widely practiced in British Colombia.

5.2.11 Key factors affecting success

Competitiveness is a function of cost and quality, including intangibles like service and brand loyalty. As already noted, to a great extent farmed salmon is a commodity. Product differentiation and consumer branding are difficult and the physical quality of farmed salmon from different producing areas is much the same, which is not surprising since it involves the same species, produced under very similar methods.

Consequently, US farmed salmon competes with imported fish almost entirely on price. There is merit in the argument that homegrown fish are likely to be fresher than fish from Chile that may have been in transit several days, but that argument cannot be readily made against farmed salmon from Canada. Moreover, by the time salmon from the Northeast or Northwest reaches southern cities, any differences become marginal. There is some market leverage in the idea of a 'homegrown' product, especially these days, and new country-of-origin labeling laws reinforce this. But the seafood industry is a global business and US consumers are very familiar with imported product (as 84% of the total is imported). Country-of-origin distinctions do not seem to be a cause for major differences in price or consumer perception of value, even though some US producer groups have tried to raise alarm about imported seafood from some countries.

The competitiveness of the US farmed salmon industry is, therefore, almost entirely driven by cost.

Product cost competitiveness

Farming costs are considered in detail in Section 5.2.7 and are usually the basis on which inventories are valued and insurance risks are calculated. From a cost competitiveness standpoint, it is important to note that salmon farmers everywhere use much the same equipment and methods. They also use similar feeds, by far the greatest cost in salmon farming, which are formulated from the same raw materials and to similar specifications in all producing countries. In fact, the world's largest salmon feed manufacturers and many of the equipment suppliers operate in all the major producing regions, so there is free flow of all technical and industrial information and a general tendency towards comparable cost structures.

Key factors affecting cost differences between farmers in different countries include the following:

- **Food conversion efficiency (FCR):** This is the ratio between food fed and weight gain. Since feed represents up to 60% of costs on the largest and most highly mechanized farms, even a small difference in FCR can have a substantial influence on cost. FCR is governed by several factors all having to do with the way the fish are cared for and their overall health status. Good water quality and attentive farm management are critical and there is no reason why a farm in Maine or Washington cannot perform equally well or better in this respect than farms in any of the other producing regions.

- **Water temperature:** Water temperature governs how fast salmon grow. Chile is generally considered to have the most favorable growing temperatures of the main salmon producing countries, allowing farmers there to grow fish weeks or months faster than farmers elsewhere. Washington State and British Columbia also have good growing conditions, especially through the winter months when the temperature rarely falls below six degrees centigrade, the level at which growth drops off. By comparison, winter temperatures in Maine and New Brunswick are much lower and can fall below zero degrees centigrade in severe winters, when a phenomenon known as 'superchill' occurs that kills salmon. At one or two degrees centigrade, more common winter temperatures, little growth occurs. In this respect farmers in Maine are at a disadvantage compared to most of their competitors

- **Feed price:** The price of salmon feed tends to be similar in all growing areas because it is made from the same raw materials. However, where these raw materials are produced locally, such as fishmeal in Chile, the cost of shipping them to feed mills is less, which results in a small saving on the final cost of the finished feed. In the case of Chile, however, this saving is more than offset by the cost of shipping the finished fish to market.

- **Labor:** The cost of labor is less in Chile than in other producing countries and provides Chile with a competitive advantage, especially in processing (see below). However, on the salmon farms themselves, differences in pay scales for labor do not make a large difference in the cost of production because most farms are now heavily mechanized. But every other input and every aspect of salmon farming that has a labor component benefits from lower cost labor. This includes production of smolts, manufacture of equipment, the cost of local services and the cost to mill feed. Producers in Maine and Washington have no competitive advantage in this area and, if anything, have higher labor costs than all other leading producing countries with the possible exception of Norway.

- **Lease regulations** US salmon farmers have been disadvantaged by the limited number of potential sites for salmon farming in Maine and Washington and regulatory obstacles to obtaining permits for them. In previous years also, permit conditions were often more restrictive and environmental monitoring requirements were more demanding in the US than elsewhere, though this is less so today as other countries have tightened their management demands. However, the leading constraint faced by US salmon farmers is the lack of potential sites, and that is a matter of geography more than regulation.

- **Biological regulations:** There are four categories of relevance to salmon production. First, the genetic origin of fish stock, is a concern where escaped farmed fish may interbreed with local strains. In Maine, salmon farmers are only allowed to use local strains, meaning that genetically improved stocks from elsewhere are not available to them.[50] Second, there are concerns about escaped farmed fish out competing local stocks, which have resulted in tough regulations on escapes. Third, it is difficult or impossible for farmers in both Maine and Washington to import seed stock (eggs or smolts) from elsewhere should they want to because of concerns about importing new diseases. Farmers elsewhere have had more latitude in this respect (although this approach is accompanied by higher risk of importing disease). Fourth, both Maine and Washington demand rigorous environmental monitoring of

[50] This includes the AquaBounty (www.aquabounty.com) genetically modified salmon for which there are concerns about both interbreeding and competition with wild fish. However, this is not a competitive disadvantage because these fish are not yet being farmed elsewhere either.

salmon farms, which in past years was probably tougher than some other countries, though all salmon farmers now have to meet high environmental standards.

- **Regulatory pressure:** Regulatory pressure in the US stems from both the complexity of the system and the scrutiny to which it is subjected by citizen groups (see Section 2.2.1). Citizen initiated lawsuits over NPDES[51] permits in both Maine and Washington have resulted in substantial costs and management burden for US growers and represent a significant competitive disadvantage for them.

- **Exchange rates:** Relative changes in the exchange rates between the US dollar and the currency in exporting countries can have a significant effect on competitiveness. Considerable fluctuations in exchange rates have occurred in recent years. The recent slide in the value of the dollar versus European and Canadian currencies has benefitted the US industry.

- **Interest rates:** In general, US banks have been reluctant to lend to fish farming businesses. Much of the credit that US salmon farmers have needed has either been supplied or guaranteed by their owners and/or through the larger salmon feed manufacturing companies.

- **Economies of scale:** During the mid-1990s, it became normal for individual farm units to produce between two million to four million pounds per cycle, which is about as large as it is generally considered prudent to go from a risk management standpoint as biological risks may be increased above this size. However, as the industry has consolidated, companies have captured other economies of scale in purchasing, processing, marketing and input supply. The salmon farming operations in both Maine and Washington benefit from being owned by large companies with synergistic interests and so, despite their relatively small size, they are probably not at much of a competitive disadvantage in this respect.

Processing cost competitiveness

Differences in the cost of processing farmed salmon have been critically important. In the mid 1990's, Chilean salmon farmers started to offer pin bone out (pbo) salmon fillets, exploiting their low labor costs in a highly labor intensive process. This advantage was made even greater because filleting meant that the extra weight of the head and frame of the salmon did not have to be shipped. This reduced the costs to Chilean farmers of both packaging and airfreight.

The success of Chilean salmon fillets forced producers elsewhere to seek less costly ways of taking the pin bones out of salmon through mechanization. In recent years, pin-boning machines have been developed that have helped to narrow the labor cost disadvantage. Highly mechanized processing plants are now the industry standard, reducing labor cost advantages still further, though US producers may not be able to take full advantage of this trend because of the relatively small scale on which they operate.

Distribution cost competitiveness

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[51] NPDES permits are National Pollution Discharge Elimination System permits issued by the Environmental Protection Agency, EPA, or by the states with authority from EPA

The cost of getting their fish to market is where US producers have a clear advantage, at least for the distribution of fresh products. Compared to farmers in Canada this is not much, but compared to the Chileans, it is substantial and likely to get more so. However, this advantage is less for frozen and other shelf stable products, so the advantage for U.S growers depends on their being a continuing premium for fresh seafood, something that is not assured as food generally becomes more expensive.

Anti-dumping actions

Historically, there have been two successful US anti-dumping actions prosecuted against overseas salmon farmers; the first in 1991 against Norwegian farmed salmon and the second in 1997 against Chilean salmon. More recent anti-dumping wars have involved the EU and third-party suppliers[52]. Though the Norwegians announced recently that they would resume actions against the duty levied on their fish, this may have little practical effect. First, the duty is on whole fish only and most recent U.S. imports of Norwegian salmon have been of fresh and frozen fillets. Second, Norwegian salmon exports to the US fell by 43% in 2010 as Chilean exports started to increase again, while Norway refocused on its strengths in the EU and Japanese markets. [53]

Whether or not these anti-dumping actions did any long-term good is open to question. On the one hand, both were originated at times when farmers in these countries had overproduced and in order to move their excess inventory they dropped the price below their own cost of production. This is not unusual in commodity markets because producers have little if any control over prices, which are simply a function of supply and demand. But it is understandable that US farmers should have wanted to ask the question: is it fair that these producers should be allowed to off load their excess product into an overseas market to the detriment of local producers who played no part in the over production? Under such circumstances, a small local industry can never hope to do well against larger competitors who are financially robust enough to survive and even prosper through market cycles. The protection given by countervailing tariffs did, undoubtedly, provide some short-term help.

On the other hand, these trade actions prevented several potential cooperative and generic marketing initiatives and, because in the case of Norway, duty was levied only on whole fish (not fillets), they may have helped to encourage the Norwegians to develop mechanized means of producing this product form. It was noteworthy how Norwegian fillets 'filled the gap' left when Chile had to reduce its production due to the ISA outbreak.[54]It is also noteworthy that the current high US prices of farmed salmon are due mostly to the problems in Chile and not to any protection from countervailing duties or obviously successful marketing campaigns for locally produced fish.

[52]In February 2003, the U.S. Department of Commerce announced final results from the third fresh Atlantic salmon anti-dumping review. Four companies were revoked from the order while two, both Norwegian owned, were left paying duties. A fourth review is pending. www.intrafish.com Anti-dumping verdict; Fjord and Stolt subsidiaries remain under order. February 5, 2002.
[53] http://www.globefish.org/salmon-may-2011.html
[54] http://www.ers.usda.gov/Data/Aquaculture/SalmonImportsValue.htm

5.2.12 Perils

Stock losses and mortality can occur on salmon farms from several causes. The industry has been established long enough now to have experienced just about everything that can go wrong and has devised management practices and strategies that greatly reduce the risk from most of them. From an insurance point of view, a key issue is the size of the loss relative to the total biomass on the farms and whether or not it exceeds any deductible or franchise[55] that might be in a policy. Large losses that exceed these limits are rare but each of the risks discussed below are common causes of insurance claims.

Diseases and parasites

Catastrophic mortality from bacterial disease and parasites is quite rare these days. Bacterial diseases have mostly been controlled by the use of vaccines and better overall stock management. This means tightened biosecurity, better feeds and better maintenance of rearing conditions, all of which provide for healthier fish that are better able to resist infection naturally. The same applies to parasites which, if they occur, can usually be controlled by medication or bath treatment, subject to local regulations on their use.

However, virus diseases are still a problem as demonstrated by the problems caused by ISA in Maine earlier and Chile more recently. Since there is no known treatment for the disease, the only method of dealing with it deemed appropriate is attempted eradication by slaughtering infected fish. Since most commercial mortality insurance policies specifically exclude such mandatory slaughter as a covered risk, these kinds of situations represent a major problem for salmon farmers. Under these circumstances, farmers in all branches of agriculture usually look to government.

ISA is a disease that is not well understood, that causes mortality among large fish in seawater and is considered a major threat to the industry. There is no treatment and a vaccine has not yet been perfected. It is believed that the only way to deal with it is through eradication and vigilant biosecurity and, since many of the farms in Maine are located quite close to each other, this requires industry-wide cooperation as well as regulatory oversight.

Eradication means the culling of stocks when an infection is identified, which is extremely costly for the farmer and the government. Eradication schemes, or orders as they are called in traditional agriculture, are usually indemnified by the USDA. In the case of ISA in Maine, the Animal and Plant Health Inspection Service (APHIS) of the USDA agreed to indemnify salmon farmers affected by ISA for up to 60% of the losses associated with depopulation, disposal, clean-up, and disinfection of fish eradicated on or after December 13, 2001 with a cap of $8.3 million.[56] A portion of the funds was also designated for the cost of surveillance programs and diagnostic support and training for veterinarians and producers. The USDA asked the Maine Department of Marine Resources to match the funds but the department said it did not have the money. In any event, this action and support of the industry by the USDA was the first time that

[55] A 'Franchise' in aquaculture insurance policies sets a minimum on the overall percentage of an insured crop that must be lost before losses are covered. However, once the franchise level is reached the claim is paid in full less any deductible. For example, a policy with a 30% franchise and 15% deductible would require that a minimum of 30% of the crop be lost in an insured event before a claim was payable. However, once losses had reached or exceeded 30% a claim would be paid less 15% deductible.

[56] Intrafish, 2002. US compensating up to 60% of ISA losses incurred. www.intrafish.com April 15th, 2002.

APHIS had taken such an active and supportive role in the US farmed salmon industry and was something of a landmark decision. Since then it has been formalized in an official APHIS policy on ISA, which provides for indemnification of farmers when depopulation due to ISA is ordered.[57]

Salmon farms in Washington have been fortunate to remain free of virus diseases to date. Since so little is known about ISA it is an obvious concern but, so far, it does not appear to have occurred anywhere on the West Coast. A virus disease that has caused problems for salmon farmers in British Columbia is Infectious Hematopoietic Necrosis (IHN) but that has not been seen in farms in Washington. However, Washington farmers do experience problems caused by the bacteria Rickettsia and by the gill parasite known as 'gill amoeba'. These have not caused mass mortality but they are difficult to treat and an on-going cause of minor losses as well as diminished fish performance.

It is generally recognized that fish are much more vulnerable to infection when stressed and fish farm practices focus on reducing stress as much as possible. This means not overcrowding fish, handling them as little as possible and doing it gently when it is necessary, and providing properly formulated feeds, as well as keeping the containment systems in which they live clean. It is also fundamental to make sure that eggs, fry, or smolts being transferred to different stages in the process are free of critical diseases before transfer.

Each of these precautions represent basic good husbandry or biosecurity and for the most part will keep the risk of serious disease to a minimum. However, there are situations, as occurred in Maine with ISA, where good husbandry is not enough, possibly because there is insufficient knowledge about how a disease is caused or transmitted and also because it is sufficiently infectious that even well managed, healthy fish are vulnerable. In these situations the risk of infection from neighboring farms is a serious threat. Such a risk is especially acute in areas where many farms are located quite close together, as occurs in Maine.

Mechanical failure – hatcheries

Most fish kills in hatcheries occur due to an interruption to the water supply resulting in fish suffocation in one or more tanks. The more mechanical steps there are in providing the water supply the greater the potential for failure. Therefore hatcheries that rely on pumps are particularly vulnerable both to failure of the pumps themselves and/or to failure in the supply of the power that drives them.

Having said that, there are many hatcheries for many different species of fish that depend on pumped water systems and that function quite reliably. Monitoring systems for key operating parameters such as water flow, dissolved oxygen, electrical supply, etc. are now readily available and well proven. Where these are linked to warning systems that notify hatchery personnel of a problem they are very effective. Supplementary generators and supplies of oxygen should be available to all hatcheries as key components of good management practice. These are also all requirements for RAS.

Structural failure – net pens

[57] AHIS, 2010. Infectious Salmon Anemia Program Standards. www.**aphis**.usda.gov/animal_health/animal_dis.../isa_**standards**.pdf

Mooring failures and failure of the net pen structures themselves have led to several major fish kills and escapes in past years. These have almost always been preventable, mostly having been due to inadequate design and/or poor maintenance, or due to farms being located in areas subject to extremely harsh conditions. As the salmon farming industry has developed, it has found that sites in well-sheltered inshore waters often suffer from inadequate water flow, with a resulting limitation on the amount of fish that can be grown in them. There are also a limited number of accessible, sheltered sites with good tidal exchange and adequate depth in all salmon producing countries, so that there has been a tendency for farms to be located in ever more exposed areas and for the farms themselves to be larger. Inevitably this has meant pushing the hardware to its limits, with the equal inevitability that there have been some failures, each one being an opportunity to learn and to improve design.

This process may be expected to continue; in many cases it provides the only way the industry can expand. Already there are companies that claim to have cage designs that can work safely in severe weather in completely exposed sites, some units being submersible as a way of avoiding the worst conditions. This is a legitimate direction for the industry to take that will expand its horizons and minimize near shore impacts, but such development is necessarily accompanied by some risk, and salmon farmers have been reluctant to adopt some of the more advanced offshore net pen designs. Ultimately, expansion to true offshore unsheltered sites is anticipated. However, before this can happen, major improvements must take place in engineering and, in the US, in the development of legislation to facilitate offshore use of state and federal waters.

Weather

Extremes of weather almost always pose risks for fish farms. For hatcheries some specific risks include:

- Ice that can block the water supply.
- Electrical storms that blow out electrical circuits and trip pumps.
- Severe wind and/or rain that can cause physical damage to structures or flooding.
- General flooding of the watercourse within which the hatchery is located.
- Drought that can lead to reduction in the water supply.
- Unusually high summer temperatures that can cause the water temperature to rise above normal, safe levels.
- Extreme heat or cold also damages or strains mechanical equipment leading to failures that may be hard to fix under prevailing conditions.

For net pens some specific risks include:

- Superchill that can occur on some farms in Maine during extremely cold winter weather when the seawater temperature falls below the temperature at which fish blood freezes.
- Wind storms that lead to large waves from exposed quarters.
- Extreme tides that cause unusually swift currents that strain the mooring systems.

- Prolonged hot, calm weather that may increase seawater temperature levels that are stressful for fish and/or lead to phytoplankton blooms - see below.

Water quality and pollution

A fundamental requirement in selecting a fish farm location is to find a water source or water body that is not polluted and in which the water quality is good enough to support fish. However, in many situations there is often a risk of water contamination from accidental spillage or pollutants from an unrelated upstream activity. Such accidents have not been common, and when they do occur insurance liability usually accrues to the polluter and not the fish farmer, but judicious site selection and warning, in some cases, can reduce risk or damage.

In Washington there is a specific water quality concern related to low dissolved oxygen (DO) levels, which can occur during the summer and fall. Low DO levels are caused by upwelling of deep, cold ocean water off the Washington coast that then flows into the areas of Puget Sound where the farms are located. Since this water is always clean and cold this provides some mitigation, but low DO's have been responsible for low-level fish kills in past years and are almost always the cause of reduced feeding activity sometime during the spring and summer months. It also represents a stress on the fish that can increase their susceptibility to disease. Farmers attempt to minimize the problem by aerating the water in the cages during these events, which helps mostly by improving water circulation rather than by elevating the level of DO itself.

Plankton blooms

Plankton blooms have caused fish kills in most salmon farming areas of the world but are more of a threat in Washington than in Maine. Almost always they are blooms of harmful algae (harmful algal blooms or HABs), but fish kills have also occurred due to the presence in the water of excessive numbers of jellyfish and crab larva at a particular time.

There has been and is on-going research into the causes of HAB's that in some cases may lead to methods of mitigation. The first line of defense against HABs is early detection. This allows time for the fish to be 'put on starve' which slows their activity and reduces their vulnerability to the bloom. Further mitigation can often be achieved by pumping (airlift pump) deeper water, which often contains less or none of the HAB into the net pens, a method that is sometimes enhanced surrounding the net pens at the surface. However, this is not effective when the bloom is present throughout the water column. Where sites are deep enough and currents are not too strong, some fish farms in BC also use extremely deep nets to provide the salmon with the option of finding deeper, cleaner water if it exists.

Predators

A variety of avian and mammalian predators can cause problems in hatcheries, including herons and raccoons. However, it is relatively straightforward to protect against them with nets and other physical barriers and most hatcheries are not severely troubled by predators.

Net pens, on the other hand, are vulnerable to large marine mammals, especially seals and sea lions, which, because of their physical size are able to push or tear their way through all but very strong protective nets.

Since marine mammal protection laws make lethal methods of control illegal, protective nets and certain deterrent devices such as underwater acoustic 'seal scarers', are the only defense that fish farmers have. This means that protective (predator) nets must be maintained in good order with all points of possible access closed. Since predator nets sometimes have to be removed or lowered in order to undertake other fish farm work, this leaves scope for human error in addition to making the work itself more difficult.

Seals and sea lions are an on-going problem for salmon farmers. Rarely do they cause major losses, but they always have the potential to do so by making holes in nets, while harassment of them with deterrent devices provides an opportunity for industry critics to find fault.

Theft and vandalism

Theft is not normally a problem in fish farms, at least not on a large scale, though it has been a problem on Chilean salmon farms. It is relatively awkward to take large numbers of live fish out of tanks or cages, so it is hard to do this unobtrusively, and harder still to sell them so there is no risk of detection. The risk of vandalism, however, is a different matter, especially given the resistance to marine fish farming of some environmental activists. Fish farms are vulnerable to vandalism in many different ways. That there have not been more instances of it reflects the good security procedures that fish farming companies normally put in place and the difficulty of accessing fish farm facilities without detection.

5.2.13 Classification of perils

Sound management can reduce the risk of loss as a result of some perils. However, some diseases and water conditions are difficult to avoid. Operating in a marine environment reduces the control over the most critical production factor, the aqueous environment. Defining insurable perils in policies and underwriting documents represents a considerable challenge in aquaculture, especially where management actions can be taken, but even they may not be sufficient to prevent losses. The question that arises in the case of loss is 'was enough done to prevent loss?' and 'can best management practice be defined to define the limits of the salmon farmer's preventive actions?'.

In private aquaculture policies , the standard perils for offshore risks might include:

- Pollution;
- Theft, malicious damage, predation or physical damage caused by predators or other aquatic organisms (but not normally by sea lice or other external parasites);
- Storm, lightning, flooding, tidal wave, collision, sudden and unforeseen structural failure of equipment, e.g. moorings;
- Fire, lightning, explosion, earthquake;
- Freezing, super-chilling, ice damage;
- The loss of oxygen due to competing biological activity or to change in the physical or chemical condition of the water, including up welling, and high water temperature;
- Any other change in concentration of the normal chemical constituents of the water, including change in pH or salinity;

- Disease; and
- Mechanical breakdown or accidental damage to machinery and other installations, including those supplying electricity, or electrocution.

The task of defining the policy components for these does not have to be faced as other serious challenges mean that salmon is not a candidate for an RMA plan that would meet FCIC standards (see next section).

5.2.14 Crop insurance issues

For salmon there also is a limited number of growers in the United States and since private insurance is available and widely used in major foreign salmon production sectors we do not recommend a federal insurance plan. The salmon private insurance may gain additional support due to its availability in other countries which have significantly more production than the United States.

- The highly concentrated ownership of the **salmon** sector is inappropriate for a US government financed crop insurance plan. This restricts the spreading of risk over a sufficient number of insureds.
- The **salmon** industry is supplied by a well-established international private insurance sector.

These two factors alone dismiss the consideration of a federally subsidized crop insurance plan. However, there are other issues that would need to be addressed in the absence of the these two powerful negative factors.

- There are severe potential moral hazard and adverse selection challenges because of the high importance of good management practice in reducing the incidence of perils in **all species and systems**. This challenge is small in the case of **salmon** as the industry has very high standards of management and is well versed in the documentation requirements for crop insurance.
- Measurement systems that can be applied with some confidence are available for **salmon** in **net cages**. However, even these are challenged by multiyear production and the occasional practice of regularly moving **salmon** between different cages and units to maximize efficient carrying capacity.
- The lack of adequate data for sound actuarial analysis for **all species** will also lead to problems of adverse selection.
- A multiyear production cycle may lead to moral hazard issues in an annual insurance plan.
- Multiple inventory assessments would be required to identify a baseline from which to measure loss. While we would anticipate commercial producers would keep detailed records, there are various challenges in accurately identifying an inventory at any point in time. For example, juveniles are entered into grow-out at different ages and sizes, the size grading and splitting of age groups and occasional mixing after splitting, each raise many difficulties in measuring inventory and lead to potential moral hazard unless the subject of exclusion.
- Most perils are closely associated with the quality of management; for example, biosecurity procedures, water quality, and stock husbandry are of critical importance. In the US salmon

sector, the standard of record keeping is likely to be high and the threat of moral hazard low, but not absent. However, there are disease and other risks that are not management or husbandry related.

- There is a lack of data that can be used in actuarial analysis of the US salmon industry. In particular, there are few published data that describe the variability in individual performance and practices. This may result in adverse selection and in high rates that may not reflect the risk (although the concept of adverse selection would appear redundant in the case of the US salmon industry with its two producers,).

5.3 Shrimp (*Litopenaeus vannamei*)

5.3.1 Status and trends

The commercial production of farmed shrimp started in the 1970s and early 1980s using the dominant locally available native tropical shrimp species; in Asia the Giant Tiger shrimp (*Litopenaeus monodon*), and in the eastern Pacific the whiteleg shrimp (*Litopenaeus vannamei*), often referred to as the Pacific white shrimp. The development of shrimp farming grew rapidly, especially in Asia.

The first spawning of whiteleg shrimp in a hatchery occurred in 1973 in Florida using a wild-caught mated female from Panama. This innovation prompted the initiation of commercial culture of *vannamei* in South and Central America. Subsequent research on breeding and rearing techniques, much of which was undertaken in Hawaii, led to its culture in Hawaii, the southern US mainland, and much of Central and South America by the early 1980s. Production tended to fluctuate with periodic outbreaks of disease, usually coinciding with the warmer and wetter 'El Niño' years. Production continued to increase, despite the periodic disease setbacks. The growth of production in Central and South America led to growing interest in Asia and soon the potential of *vannamei* in production and markets stimulated expansion in Asia. In the early 2000s, *vannamei* had exceeded *monodon* production in China, Taiwan and Thailand. However, growth in some Asian countries was delayed because of concerns over introducing diseases that had been seen to decimate populations in Central and South America. Growth in other countries had to await critical developments in producing specific pathogen free (SPF) or resistant (SPR) breeding stock. Strict quarantine laws are a critical feature of national shrimp animal health regulations.

During the 1980s and early 1990s the industry moved away from production based on post-larvae (PL) captured from the wild to one that was based on land-based hatcheries. The broodstock were still wild caught, but the PLs were produced in culture. However, disease outbreaks remained a serious constraint, and were initially attributed to poor biosecurity in hatcheries rather than the passing of diseases to the PLs from the wild broodstock. Farmers were unable to increase the stocking density of these genetically wild PLs for fear of disease. From the early 1990s more focus fell on the role of genetics and breeding to remove the threat of disease outbreaks among farmed whiteleg shrimp. During this period the capability was developed to identify the different diseases and to screen broodstock for disease and isolate and quarantine those that were disease-free for use in breeding programs. This facilitated higher stocking densities, lower incidence of disease, and easier to manage crops. Selections also resulted in an improved feed conversion rate and faster growth rate.

The development of SPF stocks of *L. vannamei* in the United States in the early 1990s facilitated the rapid expansion of US production. Following this success in the United States, domesticated non-native SPF vannamei were imported into Asia in the late 1990s. This resulted in an explosive growth in shrimp production throughout those East Asian and Southeast Asian countries that permitted importation of these SPF PLs. *L. vannamei* emerged as the leading shrimp species in local production in 2004 and by 2007 it accounted for more than 75% of total world production and was the dominant species farmed in the three largest shrimp producing countries, Thailand, China and Indonesia. This rapid growth in production resulted in a tripling of global industry crop value from 1997 to 2007, despite a rapid decline in prices as a result of efficiency gains.

The US shrimp industry only briefly shared this enthusiasm for *L. vannamei*. Historically it has suffered very serious problems with virus diseases, most of which were nonindigenous, originating either from Central and South America or from Asia. Taura syndrome virus (TSV) was identified in Hawaii, Texas, and South Carolina in 1996, infectious hypodermal and hematopoietic necrosis virus (IHHNV) in Hawaii, South Carolina, Texas, and Florida, and whitespot syndrome virus (WSSV) and yellow head virus (YHV) also were documented in Texas in 1996. While these diseases resulted in very serious losses no indemnities were paid by state or federal authorities to cover losses.

The development of SPF and SPR shrimp in the US makes interesting reading. While the US was one of the first movers into *vannamei* farming, it suffered a number of serious disease problems. In particular rent deformity syndrome (RDS) caused by IHHNV was pervasive. Scientific investigation led to the recognition that several other pathogens also limited shrimp production and consequently the US initiated research programs to develop SPF stock under rigid biosecurity protocols. Initially, SPF stock was screened for IHHNV, protozoa (microsporidians, haplosporidians, and gregarines), and metazoan parasites (larval nematodes, trematodes, and cestodes). Later work extended the development of excludable pathogens to WSSV, YHV, TSV and a number of other less serious viruses.

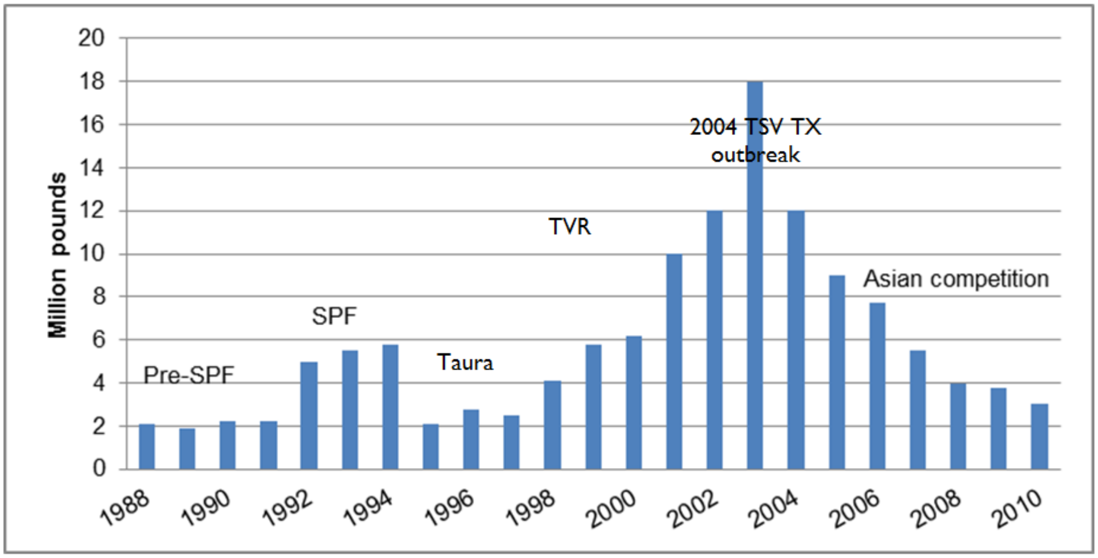
US production has been contracting very rapidly after reaching a peak in 2003, and is now an insignificant part of the US aquaculture sector. The main reason has been a combination of intense competition from a rapidly expanding, and increasingly efficient Asian industry and a second outbreak of TSV in 2004 in four farms in southwest Texas (the first was in 1995). Shrimp mortality ranged from 80-90 percent. This outbreak proved that the use of SPF stock alone could not control the challenge of TSV in the United States. The outbreak was caused by a different strain to the one eliminated in the Taurus virus resistant (TVR) stock and has become established by other methods such as migratory birds or insects, imported shrimp, or persons or transport coming onto the farm.

5.3.2 Output (volume and value)

Global marine shrimp production expanded rapidly from 450 million pounds in 2000 to over 5 billion pounds in 2010, most of which was produced in Asia. In contrast, US marine shrimp output in 2010 was 3 million pounds. US farmed shrimp production is valued at under $10 million, although prices have varied considerably in recent years.

Figure 16 below shows the output of the US farmed shrimp industry since 1988. Specific periods are identified that relate to disease impact and the development of SPF and SPR stock, and the eventual near-demise of pond farmed shrimp because of international competition. The recent upswing in global shrimp prices has provided some optimism for those with shrimp ponds and local industry observers suggest that the decline will be halted in 2011 and 2012 as long as these high prices persist (see Figure 21).

Figure 16: US farmed shrimp production, in million pounds



Source, Wyban (to 2003) and Promar (post 2003)

Some farms have diversified some of their ponds away from shrimp and also grow tilapia and red drum. Currently less than a one third of the acres allocated for shrimp farming are in use. Ponds can be returned to shrimp production relatively easily. New farms face a major hurdle gaining new permits, unless they are zero discharge.

5.3.3 Number of producers

There are no more than 15 pond shrimp companies operating in the United States and its territories, with 85% of the production from five Texas farms.

In addition, there are a small number of inland RAS systems producing shrimp. These have a very checkered history, with press statements on output ambition yet to be achieved. Several have folded, and some have been reengineered to try to overcome system problems. Natural Shrimp in Texas has recently restarted production after a period adjusting its system and overcoming production problems. Marvesta Shrimp Farms in Maryland was under reconstruction during the first nine months in 2010, but has now restarted. The Shrimp Farm Market in Michigan is operating on a very small scale selling locally for a short period at weekends. Magnolia Shrimp in Kentucky has folded, despite substantial assistance from the Commonwealth of Kentucky and the federal government to develop it as a demonstration project. There are several other RAS startups that have suffered failure.

5.3.4 Concentration of ownership

Currently, marine shrimp farming in the US is a highly concentrated industry. In 2010 five Texas farms accounted for roughly 85% of the shrimp produced in the US (about 3 million pounds). Four of those accounted for 96% of Texas production and an estimated 80% of US production. The remaining one-half million pounds of shrimp is grown in smaller operations in several states around the US as noted in section 5.3.5 below.

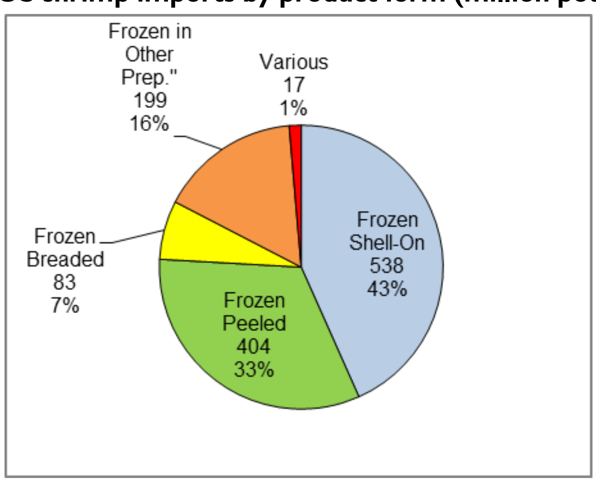
5.3.5 Regional distribution of production

There are five companies along the south coast of Texas that use seawater for their food shrimp ponds (Harlingen, Shrimp Farm, San Tung, Bowers, Bowers Valley and St. Martin Seafood). In addition there is one pond shrimp farm in Florida (Woods Fisheries), two in Alabama, and very small farms in Hawaii, the Commonwealth of the Northern Mariana Islands (CNMI), Guam and South Carolina. An Arizonan company (Desert Sweet Shrimp - using low salinity well water) stopped production but now apparently has a new investor and is reportedly going to start up again next year. The Alabama farms are both inland farms using low salinity groundwater (Green Prairie and one very small farm). No data was reported for Hawaii in 2010. Hawaiian production is largely focused on broodstock and PLs for export. We understand that there is little or no production of food shrimp in Hawaii today.

5.3.6 Markets

The US shrimp market has five broad shrimp market segments, mainly serviced by imports. A breakdown of the composition of the imports is shown in Figure 17. The most important segment is the frozen shell-on segment (43%), followed by frozen peeled shrimp (27%) and frozen prepared (16%). Breaded products (7%) and various other preparations (1%) make up the remainder. This latter group comprises live shrimp, fresh shrimp, dried, salted and canned among other miscellaneous presentations. The US sector is mainly focused on the latter category.

Figure 17: US shrimp imports by product form (million pounds, 2008)



Source: NMFS Fisheries Statistics Division

Each of these markets differs in character.

- **Frozen shell-on**: This, the largest segment is further segmented by nine size groups. The size is denominated by the number of headless shrimp or shrimp tails per pound. These size groups are grouped into large, medium and small size groups. Competition in all sectors is heavily influenced by price and where capture supplies compete. The prices can be very volatile depending on the availability of capture supplies. The larger sized product is more easily differentiated and the market can be more stable.

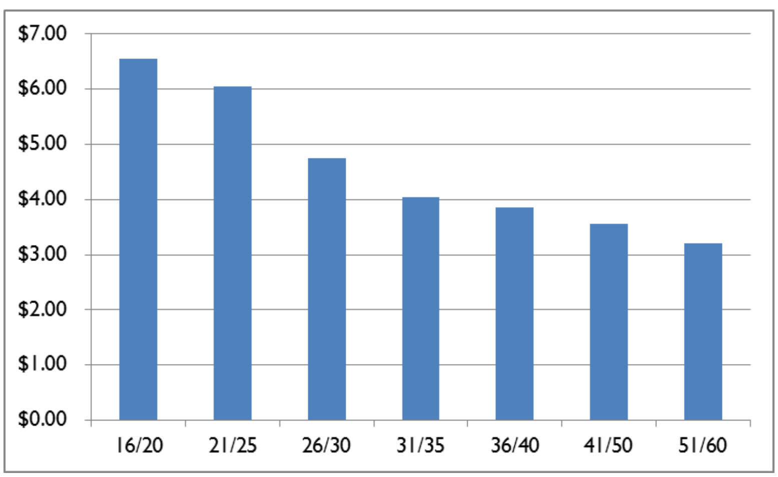
- Figure 18 below indicates the nature of the premiums paid for the larger products in the US market.

  - The large size groups comprise 10, 12, and 15, which are mainly from capture fisheries and 16/20 and 21/25 (from aquaculture). These larger shrimp are aimed more at the upper end of the market, and here products from India, Indonesia, Bangladesh and Vietnam compete. Larger size shrimp have exhibited less price volatility as they are selling to upper-end markets.

  - The medium sized products fall into the 26/30, 31/40 and 41/50 sizes. This segment is dominated by the Southeast Asian countries and Ecuador. Until very recently, the prices in this category have fallen dramatically since the early 2000s. This is a category of extreme competition in the US market and some Southeast Asian origins have to pay anti-dumping charges. Brazil was at one stage a player in this market, but it largely withdrew to focus more on growing its own domestic market.

  - The small sized products include all sizes 51 and over. In this segment there is considerable competition between capture and aquaculture origins. Again competition is very fierce and prices have plummeted since 2005.

Figure 18: Shrimp price ($/lb.) by size (end of July 2010) - MX west coast whites (New York, Average FOB prices, $/lb., as reported by original importers)



Source: Shrimp News International

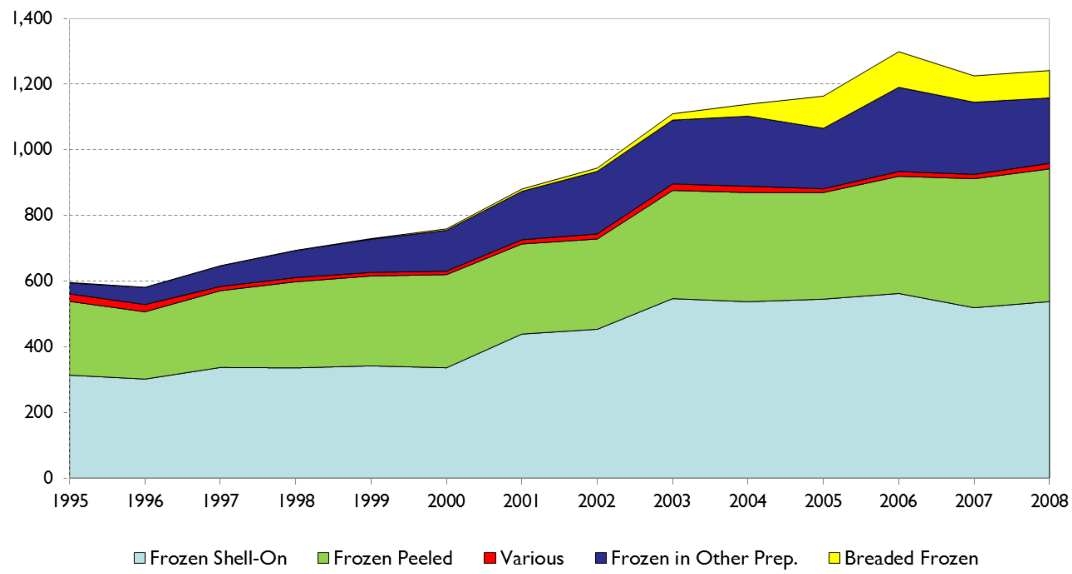
- **Frozen peeled:** This segment is dominated by Asian suppliers such as India, Indonesia, Thailand and Vietnam. Most of this segment originates from aquaculture.

- **Frozen prepared and frozen breaded:** This segment represents a wide range of processed products that offer some value added because of convenience either for food service or for consumption in the home. This segment is dominated by Asian suppliers, largely on account of the advantages in labor costs at processing plants. The breaded product is limited to smaller sizes and is now a price driven commodity market.

- **Other presentations:** These are largely niche markets. Mexico, for example, is the only supplier that is well placed to supply some of these markets to neighboring states in the US. However, very few Mexican products are sold fresh. US trade data suggests that a number of Asian countries send small volumes of fresh shrimp by air.

Most product is sold as frozen shell-on, although the proportion imported that are breaded or in some other form of preparation has been increasing steadily (Figure 19).

Figure 19: US Shrimp imports - Volume by form ('000 pounds, 1995-2008)

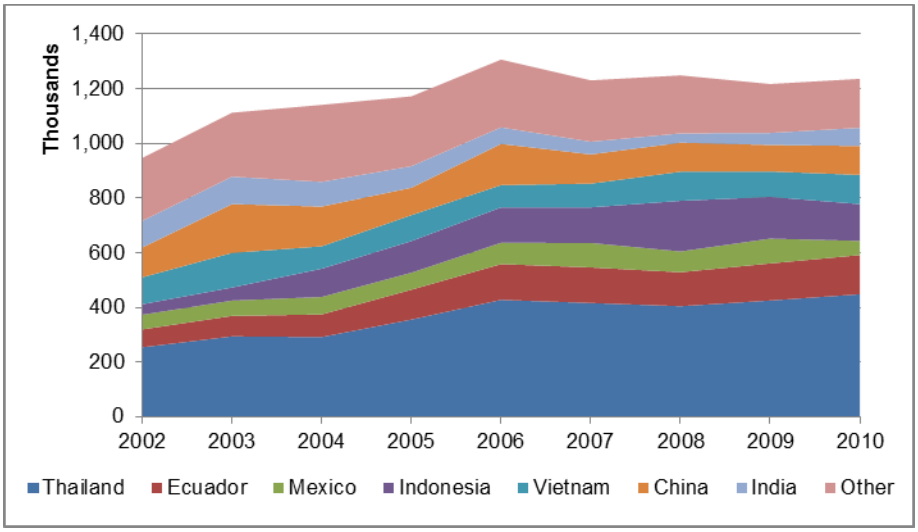


Source: NMFS Fisheries Statistics Division

The US consumes roughly 1.5 billion pounds of shrimp annually, and the bulk of supplies are imported. In 2010 the US imported 1.2 billion pounds of shrimp worth $4.3 billion. US production represents less than 0.25% of the total volume of US imports.

Figure 20 illustrates the range of countries supplying United States with a number of shrimp species, the vast majority of which will be *L. vannamei.* Thailand has been the most important supplier, although Ecuador, Mexico, Indonesia, Vietnam, China and India are also regular suppliers.

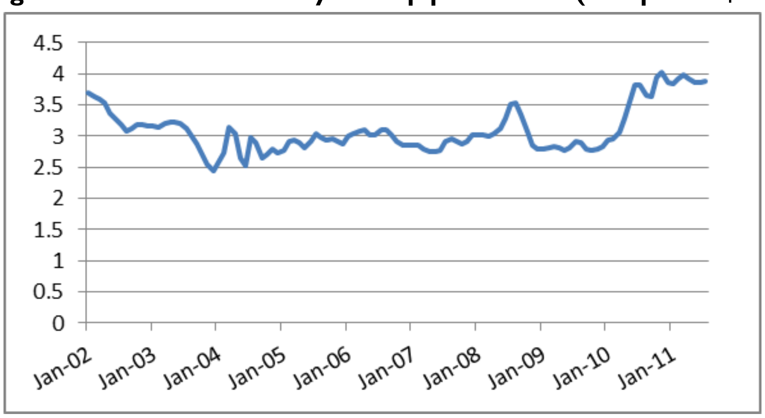
Figure 20: US shrimp imports by country and volume (thousand pounds)[58]



Source: Urner Barry

Across the board the value per pound of imported shrimp increased in 2010 over 2009 and in most cases to their highest prices in six years because of strong demand (particularly from China) and a southeast Asian shortage (with weather issues in Indonesia) (see Figure 21). This eased the pressure on US shrimp producers and industry observers suggested that ponds that had previously been left fallow or used for other aquaculture production could be brought back into operation if these prices persist.

Figure 21: The Urner Barry shrimp price index (composite $/lb)



Source: Urner Barry

[58] The headless, shell-on (HLSO) shrimp index is a measure of general conditions in the shrimp market. It is not a reflection of any single item. Urner Barry historically tracks all of the market quotations which should be consulted for individual items. The shrimp index is calculated using an average of Urner Barry market quotations; additionally the quotes are weighted based on the import volume of each count size. Shell-on shrimp imports from the Black Tiger producing countries and White producing countries of Thailand and Indonesia have been adjusted to reflect those countries' significant shift in production from Black Tiger to *L. vannamei*. Shrimp imports from other countries are divided into either Black Tiger or White producing countries.

The value of imports per pound increased by 23% for India and 20% for Mexico last year, while China and Thailand, much larger producers, only experienced a 6-7% increase. The average increase was 15% or $0.47 per pound. Table 10 below illustrates the import value per pound for the major suppliers. Mexico is relatively expensive, limiting their competitiveness in recent years, while Vietnam and India tend to produce larger giant shrimp that sell at a premium.

Table 10: US unit value of shrimp imports by country($/lb)

	2005	2006	2007	2008	2009	2010
Thailand	2.76	2.99	2.98	3.18	3.19	3.38
Ecuador	2.49	2.48	2.37	2.74	2.43	2.84
Mexico	5.17	4.13	4.01	4.47	3.67	4.39
Indonesia	3.22	3.32	3.44	3.41	3.22	3.66
Vietnam	4.67	5.26	5.30	4.52	4.11	4.81
China	2.06	2.20	2.21	2.37	2.42	2.59
India	3.98	4.18	4.22	4.21	3.79	4.65
Other	2.97	3.09	2.97	2.96	2.71	3.10
Total	3.13	3.17	3.18	3.29	3.10	3.47

Source: Urner Barry

There are many tariffs and other trade-impacting actions affecting trade in shrimp. In particular, countries with domestic shrimp production and processing industries have found various ways to protect vulnerable domestic production from foreign competition. Market access has been restricted for a number of reasons including unfair pricing, food safety, environmental, child labor, etc. There has been pressure from US domestic suppliers to restrict market access. As a result, anti-dumping duties have been imposed on a number of farmed shrimp competitors (e.g. Thailand, India, Ecuador, Vietnam and China) and on Mexican captured shrimp[59]. As a result some US farms have received the benefit of Trade Adjustment Assistance payments. As the above figures suggest, these measures have had little effect.
Some large Texas producers sell shrimp to processors that then trade it into frozen product markets. This market is highly competitive. Many farmers sell to local markets and restaurants during the main harvest period that runs from August to October. In Texas, the volume sold during the harvest period is too large for local markets and hence the frozen market is the only viable option.

There are also specialty markets for shrimp among upscale retailers. For example, Wegmans, an upscale grocery store chain with more than 70 locations, is currently looking for a new supplier because their 'green' supplier in Belize has recently closed down. There is also an organic market that will buy shrimp at a premium. Thus, US growers seek out niche markets to protect themselves from intense overseas competition.

[59] The US lowered its anti-dumping duty on Thai shrimp in early August 2011(from 1.11-4.39% to 0.41-0.73%). The reduction came after the World Trade Organization's ruling that the US was breaching the trade body's regulation on calculation of duties against unfair prices. This was the fifth time that the US has reduced the duty since the WTO ruling. This is now less than the duty on Indian imports, one of Thailand's main competitors.

5.3.7 Price data

Regular price data are available on shrimp as they are widely traded in volume and easily described. The most comprehensive source is Urner Barry's Comtell online source. This quotes ex-Warehouse, East or West Coast prices for many origins and counts per pound (varying from 2-3 to 131-150) and either 'shell-on, headless' or 'peeled, headless and finished count'. There is also information on wild and farm raised. There is no data published on US origin farm-raised.

There is also data available from the Fulton's Fish Market Weekly Price, New York Frozen Prices. Currently selling prices, ex-warehouse New York as reported by receivers, are available for shrimp peeled and undeveined-Gulf #5 and shrimp headless, shell-on Gulf white and brown.

Some of the US farmed shrimp producers are reported to be selling all or part of their production in local or specialty markets. These will differ regionally and may not be correlated with the quoted prices.

5.3.8 Availability of production history and other data

There is limited industry data available on the marine shrimp industry in the US. The Texas Aquaculture Association (TAA) regularly produces industry statistics identifying Texas producers by size and intensity of production. There are some data describing the extent to which performance varies by farm, and the TAA has recently posted data that illustrates the extent to which production can vary by pond using a Florida farm as an example (see Section 4.3.5 and Table 11). The data supplied illustrates substantial variations in survivability and performance by farm and pond. Low DO levels were identified as the key reason for low survivability in the ponds 2 and 5 on the Florida farm. The farm has since introduced continuous DO monitoring to be able to combat these low levels with aeration.

Table 11: Individual pond production summary from a Florida farm

	Pond #					
	1	2	3	4	5	6
Harvest (pounds)	17,127	11,420	19,439	17,133	6,963	18,286
Pounds/Acre	4,472	2,884	4,368	4,294	1,612	3,993
Size (grams)	22.74	29.13	23.37	24.86	23.21	20.34
Count	19.95	15.57	19.41	18.25	19.54	22.30
Survival	56.2%	26.0%	55.1%	48.6%	19.9%	58.5%
FCR	1.46	2.14	1.33	1.46	3.72	1.49

Source: G Treece, Texas Aquaculture Association.

Survivability is reported to average around 50% in general, although there is substantial variation, and Thai producers claim higher rates.

Industry observers in Texas have noted that production yields have declined in recent years, although the reasons are unknown.

There is little data that provides an accurate picture of production costs. Feed is regularly reported as 50 to 70 per cent of total costs, although different levels of intensity demand different levels of feeding. Costs per pound in the United States tend to increase with greater stocking intensity as more feed is required and energy costs will be higher because of a higher demand for aeration. Clearly the system adopted will depend on the location, capital investment, and cost of key inputs such as feed, PL, labor, fuel, and energy.

5.3.9 Biology

The whiteleg shrimp *Litopenaeus vannamei* is a marine crustacean belonging to the order Decapoda and the family Penaeidae. The body is translucent, with bluish green pigment reflecting light. *L. vannamei* is omnivorous, although it is often characterized as carnivorous and requires a high-protein diet. The whiteleg shrimp is native to the tropical Eastern Pacific coast extending from Sonora in Mexico to southern Ecuador. Here, water temperatures rarely fall below 20°C. US temperatures fall outside that level, meaning that production is confined to a production cycle that is limited to the warmer months. Spawning takes place in the open ocean, and then the PLs move inshore to spend their juvenile, adolescent and sub-adult stages in coastal estuaries, lagoons or mangrove areas before moving out again into the ocean to depths of several hundred feet when they are mature. In the wild both males and females mature at 6–7 months, although this is modified by domestication and breeding for commercial aquaculture.

Nauplii live on their yolk reserves and then in their larval stages live on phytoplankton and zooplankton, and are carried towards the shore by tidal currents. After molting (5 days), PL move inshore and begin feeding on dead organic material, worms, bivalves and crustaceans as they mature to adulthood. They can grow to be nine inches in length. Whiteleg shrimp are very sensitive to water temperature and salinity. Ideal aquaculture conditions are water temperatures between 28-30 degrees centigrade and salinity of 33-40 ppt (parts per thousand). Juveniles are susceptible to very low salinities and to high temperatures in the wild. In culture, great care must be taken when raising PLs to reduce salinity slowly to that of the eventual pond salinity.

There are several biological factors that make *Litopenaeus vannamei* ideal for aquaculture. First, their nutritional requirements are modest compared with most other species of shrimp. They can be fed on lower protein feeds (which reduces feed costs and the potential bacterial load on the pond environment). In addition, as a result of domestication and selective breeding, these shrimp grow well in densely stocked systems and maintain reasonably uniform size. On the other hand whiteleg shrimp are very vulnerable to serious diseases, especially when farmed in intensive systems. Indeed, shrimp would not have been a successful farmed product and surpassed *L. monodon* without major breakthroughs in shrimp genetics and breeding.

5.3.10 Production system

Broodstock genetics is important with all aquaculture production. Getting high quality selections of SPF or SPR PLs from a reputable hatchery applying superior genetics is critical for efficient shrimp production and reduction of disease risks. One broodstock facility is in Texas and others are in Hawaii.

In the hatcheries, the eggs are placed in hatching tanks for 12-18 hours. There is a fifty per cent survival rate of seed stock. There are four larvae stages. All four of these stages take place in larval rearing tanks. When the shrimp reach 1-3 grams in size they are transferred to ponds or tanks. This is the size and stage at which most aquaculture farmers receive their shrimp stock. Unlike other forms of aquaculture, it is less common for companies to have their own hatcheries. The operation of shrimp hatcheries is a specialist activity involving expensive investment in the facilities and expertise to supervise breeding and maintain high levels of biosecurity. Some US shrimp hatcheries have been exporters of stock to Asia and Central and South America for many years.

Once the shrimp have been transferred to their grow-out location it will take four to six months in extensive ponds or three to five months in intensive tank systems until they reach harvest weight.

There are several different ways of producing shrimp in ponds. The most important distinction is in terms of their stocking intensity. The average size of Texan ponds is very large, often tens of acres in area. None of the US pond systems fall into the most intensive systems (see below).

Semi-intensive systems are ponds that have biomass of less than 4,000 kg per hectare and stocking densities of 10-40 PL per square meter. There is regular water exchange through a pump, but little aeration. The ponds may be fertilized and the shrimp feed on natural food in the water with regular feed supplementation.

More intensive systems rely on higher stocking rates and more feed. The ponds are stocked at densities of 40-100 PL per square meter and have biomass greater than 4,000 kg per acre. There is heavy aeration to provide the necessary water circulation and oxygenation. Higher intensities involve much higher yields, although costs are higher and very high management standards are required. Two of the Texas farms operate levels of intensity that can be categorized as intensive, although not very intensive.

The amount of water required to grow marine shrimp has also been declining, largely due to pressure for farms to reduce their environmental footprint in adjacent coastal regions. Technology to enable the reuse or recirculation of water has resulted in a shift away from flow-through systems, which were popular in the 1990s. These systems required as much as 4,500 gallons of water to produce one pound of shrimp. However, now water exchange has been significantly reduced, and is largely required to offset evaporation. On most Texas farms daily exchange will not exceed 3%, with new technologies promising zero exchange.

Some mention should be made of RAS systems. These are termed super-intensive and as with all RAS systems they rely on high levels of management, high stocking rates, and high growth rates with zero (or near-zero) discharge of waste water. The grow-out period is reduced and several crops can be obtained per year (three to four). So far none of these systems have achieved significant success. They are expensive to install and require very high levels of management and strong biosecurity.

5.3.11 Length of production cycle

In the US the semi-intensive and intensive systems involve placement of the PLs in ponds when the water temperature reaches 24°C (usually late May to early June, meaning that PLs are stocked in March). The grow-out period takes approximately 120 to 180 days. Harvest takes place between late August and October with the end date hastened if cold temperatures are threatened. In Texas all the shrimp must be harvested before the end of October. No overwintering is possible and the US is normally limited to one crop per year, although some may take two short crops to supply very small product. In tropical areas, production is available over a much longer period. RAS systems allow continuous production with control over water temperature.

5.3.12 Key factors affecting success

Shrimp production in Thailand is at the leading edge in terms of the application of a science-based industry. They have invested heavily in scientific support and an education campaign to improve productivity in their small intensive ponds. The threat of viral diseases (see Section 5.3.1) means that it is essential to use genetically improved SPF and SPR PLs, to implement intensive biosecurity measures and to reduce water exchange that might introduce disease from outside the farm. Also, intensive systems rely on high quality dense feeds and carefully controlled feeding, engineering that can efficiently maintain oxygen levels, water quality, emergency systems back-up and removal of waste, and the maintenance of microbial communities to cycle wastes and increase overall feed conversion rate. These bacteria assimilate nitrogen compounds and do not contribute to variations in DO.

Introducing efficiencies in genetics, hatcheries, controlled pond systems and the systemization of management has been the basis of success. This has seen an increase in survivability, reduced pond failures and had a major impact on growth rate. McIntosh (2011), a manager of one of the leading Thai companies, emphasizes the critical role played by genetics. He reports that in Thailand in 2004 it took 128 days to reach 25 grams, while today that weight is reached in between 70 and 80 days. He also reports a feed conversion rate dropping from 1.6 to 1.3 over the last 4 years and falling energy costs per kg of output.

As in most animal production, the cost of feed is a large percentage of the total variable costs. Feed costs for shrimp are continuing to increase and are higher in the US than in Asia. In 2008 they increased by 25%. Even with an improved FCR, feed is still a large portion of all operational costs.

5.3.13 Perils

The list of perils affecting shrimp resembles those for pond culture of warm water finfish with one major exception. Viral diseases represent a major threat and have continued to present problems, although these are reduced with the stocking of SPF and SPR PLs. The leading viral challenges in the US have been from WSSV, TSV, YHV, and IHHNV, each of which have accumulated billions of dollars of losses to the industry. WSSV is considered to be the most lethal, sometimes accounting for 100% mortality. Also, there are some other minor viruses such as baculo virus that do not impact production seriously. The US Marine Shrimp Farming Program[60] (USMSFP) was developed to fight these diseases and its work resulted in the SPF and SPR broodstock and PLs.

Disease transmission in the US has been associated with waste from processing, bird depredation, and infected post-larvae. TSV is thought to have been transmitted by birds infected by feeding on diseased shrimp. Some viruses can survive in a bird's digestive tract and be passed in its feces.

However, shrimp are also known to be vulnerable to a range of pathogens including bacterial, fungal, rickettsial, protozoan and metazoan infections. Various water treatments based on formalin are available to deal with some protozoan parasites, although the size of the pond may limit the efficacy of this. Apart from this and methanesulphate (an anesthetic during live transport), no other drugs are permitted. Oxytetracycline has been used in other species as part of a medicated feed treatment for bacterial diseases. Protracted studies have not cleared it for shrimp, but since 2011 it can be used under

[60] This program has been wound up in 2011 as US shrimp production has contracted.

supervision as part of a study under the auspices of the US Fish and Wildlife Service's Aquatic Animal Drug Approval Partnership Program. Some are hopeful that probiotic bacteria may be identified that can be used in the management of bacterial diseases such as vibrio. Other perils may be associated with poor nutrition, feed supply contamination, algal blooms, and toxins.

US shrimp farmers have excellent facilities available for disease diagnosis. The Aquaculture Pathology Laboratory at the University of Arizona is recognized internationally for its shrimp disease diagnostic and certification services and is the Office International des Epizooties (OIE) reference laboratory for shrimp pathogens for North America.

A rapid change in water parameters, particularly dissolved oxygen, can cause serious losses (levels of 5 to 15 are essential). As with other aquaculture, close monitoring of conditions and immediate remedial action is required to prevent losses. Again the size of some ponds in Texas may limit the extent to which some water quality treatments are possible. The threat of bacterial and fungal diseases can be reduced with good management practices. This includes fallowing and cleaning ponds between use, reducing water exchange, and good biosecurity.

Predators can be a problem, particularly in large ponds where bird predation cannot be limited by netting.

Production is vulnerable to a range of catastrophic weather and weather related events. Death will occur if water temperatures fall to the very low 20 °C. Hurricane, tornado, and floods can have devastating effects. It is also subject to disruption of electrical supply or the loss of other key inputs.

5.3.14 Classification of perils

The risk of losses from all major diseases can be reduced through good management practices such as biosecurity, including the purchase of SPF/SPR PLs, pond and water management, and predator control. Those that are subject to management practices cannot be insured.

There is a risk of novel unknown diseases as for all farmed species. We conclude that only these unknown diseases and naturally occurring events are insurable. The coverage of losses where mandatory depopulation is required to restore industry confidence should be the subject of federal government indemnity schemes. No indemnity is available to the shrimp industry as other methods of control are considered adequate.

5.3.15 Crop insurance issues

Based on our review, we do not believe that credible data exists to build a rating program for an insurance program for aquaculture. We also believe that the overall number of farming operations for shrimp is too small to create a federal insurance program specifically to cover a few growers who may or may not purchase the insurance.

- Shrimp (*Litopenaeus vannamei*) production is a very small industry that faces ongoing competitive threat. The industry has highly concentrated ownership. There is unlikely to be enough interest for the risk to be spread over an acceptable number of insureds and geographic areas.

- The industry is under considerable economic pressure. We doubt that there would be a willingness to pay the premiums required to cover an industry with high production risks.
- The shrimp industry is vulnerable to many diseases and other perils and is a risky operation. Losses are large and regularly incurred. We understand that no shrimp industry is insured globally because of the very high risks. The Thai industry has recently tried to combine the efforts of the Thai government (to cover systemic risks), a proposed mutual insurance company, and the agricultural reinsurance industry to develop an insurance institutional framework for shrimp. That is in process. The Thai industry is considerably more advanced in terms of technologies than the US industry.
- There is a lack of data essential for actuarial assessment. For example, there is no data describing the incidence of disease or other perils, the cause of the low survival rate, or prices when sold locally. There are also no data adequately describing individual production variability. This lack of data inevitably results in adverse selection and the identification of rates that are likely to be much higher than the industry can pay.
- There is likely to be difficulty identifying the size of loss in ponds as there are no accurate methods for determining losses (see Section 4.3.2). Identification of inventory and the volume lost at a specific point in time would be challenging. Proper records should be kept, because if there is a loss, data is needed to prove juveniles entered into ponds, feed used, water temperatures, feed conversion results, growth rate, harvest times, what is being harvested, mortality, and all water management practices. It is difficult to identify standard growth rates or mortalities to assess inventory because of the range of conditions and management practices under which shrimp are grown.
- Most perils are closely associated with the quality of management. Management affects the design and servicing of the pond, the quality of the water, the treatment of diseases or parasites, and biosecurity. Thus, there is danger of moral hazard, and adverse selection.
- Shrimp produced in RAS is extremely risky as entrepreneurs struggle to reproduce the theoretical benefits in a commercial environment. The small RAS shrimp sector is very diverse. The absence of sound statistical description of the character and experience of these systems poses serious challenges in actuarial analysis. The determination of rates will include a factor that takes account of the poor descriptive data. Consequently, premiums are likely to be too high for an industry under substantial pressure already.

5.4 Red drum (also redfish - *Sciaenops ocellatus*)

Red drum are native to the Gulf of Mexico and southern Atlantic US states. They are a popular sport fish as well as being commercially caught. Their numbers in the wild have been threatened in past years by over fishing. This prompted the development of replenishment programs for them, notably in Texas where millions of juveniles have been released from hatcheries into the sea. [61] Hatchery methods use eggs taken from captive red drum broodstock held in tanks, that on hatching are released into salt water ponds

[61] http://www.lib.noaa.gov/retiredsites/japan/aquaculture/report22/mceachro.html

in which natural plankton species have been encouraged to bloom and which provide food for the newly hatched larvae. The fish are then grown for about 30 days until they reach 30mm in length before being released into the Gulf of Mexico.

Commercial farming of red drum in the US uses similar pond production methods as for the hatchery, except that the ponds are larger and the fish are weaned from live food growing naturally in the ponds to dry pelleted feed. This increases the weight of fish that can be grown in a given area. Commercial farm ponds are usually about 5 acres in area and use either bay water or saline ground water as their water supply.

In 2009/10, there were five commercial red drum farms in Texas with 710 acres of pond in total with about 600 acres of grow-out ponds. Production can reach up to 10,000 lbs per acre per grow-out cycle with the time taken to reach market size of 1.5 lbs to 3.0 lbs being 11 – 18 months.

Total annual production was estimated by industry observers at 2.5 million pounds in 2010, with a farm gate market value of about $7 million (cited in Treece, 2011). Treece estimated that production was 4 million lbs in 2008 with a farm gate value of $9.6 million.

The farm gate price has varied between $2.40/lb to $3.15/lb in the past three years and is influenced by the price of wild-caught red drum and also imports from China where red drum are farmed in coastal net pens. The price has come down from a high of about $4.00/lb some years ago, which encouraged the start of this aquaculture industry. However, lower prices and increased costs for feed and fuel in recent years have created difficulty for the industry and are probably the main cause of the apparent fall off in production. Additional difficulties are created by:

- Toxic marine plankton (dinoflagellate) blooms in the ponds, which kill fish and which have reportedly been the reason that several brackish water farms have closed.
- A regulatory climate that makes it difficult or impossible for farms to expand if they want to, the only option being to buy existing shrimp farms that are already permitted, or for the shrimp farms themselves to switch production to red fish.
- A fillet yield from Red Drum (edible meat recovery) of only 28%. This is low compared to most fish and means that at a farm gate price of $3.00/lb, the cost of the fillet is $10.70/lb before processing, packaging and distribution costs. This makes it an expensive fish by comparison to other species.

Under present circumstances, the outlook for the industry does not look encouraging and it is hard to see how significant expansion is likely.

5.5 Amberjack (yellowtail or kampachi - *Seriola rivoliana*) and moi (*Polydactylus sexfilis*)

These species are considered together because they have both been the subject of new aquaculture businesses in Hawaii that have sought to develop the concept of open ocean aquaculture where net pens are deployed that are designed for use in the open sea. Often this means that the net pens are designed to be able to submerge in order to avoid rough weather, or to operate in a permanently submerged state.

Two companies have pioneered this development – Cates International Inc, now Hukilau Farms, and Kona Blue Water Farms Inc. Both began using a design of net pen called a SeaStation®, but the latter is now switching to a heavy-duty floating collar design.

Both of these species are native to Hawaii waters. This is a critical issue as potential escapes are a major concern. None of the juveniles used in the enterprises have been the subject of intensive breeding or selection programs, consequently, there is substantial potential for improved productivity.

Both companies have experienced a somewhat turbulent development and currently both are in the process of restructuring and/or re-equipping their sites. When taken together at their peak production, their combined production was probably nearly 1,000 metric tons[62] but, presently, it is much less than this. Therefore, this new industry is still in its formative stages and its rate of growth is difficult to forecast. In July 2011 new Hawaiian state regulations for aquaculture have been enacted, providing greater incentive for ocean and land-based aquaculture.[63] Currently it is difficult to assess the extent to which this will promote the growth of offshore aquaculture within state waters. The potential is substantial because of the vast amount of sea area available to farm if the technology becomes reliable and the concept is applicable to other marine species in all other US coastal states. From an insurance point of view, the risks comparable to salmon farming and therefore quite well understood, albeit with new challenges related to the open water location of the farms and the unknowns of starting to farm new species. So, if and when these challenges are overcome, there is potential for rapid, large-scale development.

5.6 Summer flounder (*Palalychthis dentatus*) and sea bream (*Sparus aurata*)

Both of these fish species are being produced by a company called Local Ocean in Greenport NY in its recirculated aquaculture system (RAS) with a combined volume of 200,000 pounds in 2010, which is forecast to increase sharply in the next two years. Local Ocean is the only US company producing these species presently and describes its approach to aquaculture on its website as follows:

> *"To date, in Greenport, New York, we have built and operate the world's first (and only) commercial zero-discharge 100% recirculating aquaculture system. In essence, our facility is a controlled and self-balancing micro-ecosystem where we are able to grow a variety of saltwater fish wherever there is a local market."*

It has plans to expand production to California and grow four other species - Amberjack, White sea bass, Black sea bass and European sea bass. The sea bream it is producing now is also a European species.

In May 2011, one of the partners in the company filed a lawsuit against the company for breach of patent. GFA (Grow Fish Anywhere) is an Israeli company backed by international venture capital funds and it claims that the patent belongs to its founder, a professor at Hebrew University, Jerusalem. The other partners have counter-sued and the issue is being fought out in a Tel Aviv court.

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[62] Estimate by John Forster.

[63] However, summing up the level of resistance to offshore aquaculture, Food & Water Watch and Hawaiian environmental group KAHEA filed a lawsuit against the federal agencies that had granted Kona Blue the first commercial offshore aquaculture permit issued in the United States on July 6, 2011. They allege that the federal government lacked the authority to grant the permit and failed to adequately assess the environmental impacts of the company's offshore aquaculture operations as required under federal law. (Seafood news, August 4, 2011)

SECTION 6: FEASIBILITY RECOMMENDATIONS

6.1 Criteria for assessing RMA insurance plan feasibility

6.1.1 Aquaculture production systems and crop insurance

Aquaculture production systems fall into four broad categories: ponds, raceways (where water flows through containment channels), recirculating systems (RAS, usually in tanks or containment structures with engineering to circulate water and manage its quality), and net cages (either in lakes or in sheltered inshore marine locations).

The key issues relating to crop insurance are primarily influenced by the production system, despite some species differences. In general, aquaculture production of individual species favors one production system rather than another, although in some species there is the option to use alternative production systems. Economics and location may both play a part in deciding the production system to adopt. For example, raceway systems are restricted to areas where there are large volumes of good quality water. Indoor recirculating systems involve higher levels of investment costs, but offer the opportunity of higher revenue from year-round production. Some species can only be produced in warm water and hence their production is limited in locations that are more northerly unless there is heating.

Management is critical in all aquaculture as each species demands healthy initial stock, specific water conditions, careful attention to density of stocking, appropriate feed and feed routines, and consideration of fish health. Great care has to be taken to ensure that water containment structures are appropriately prepared for production and that the engineering provides a suitable water environment. Biosecurity measures must be strict to prevent disease, and measures must be taken to prevent predation.

Each of the species we have examined feature key management considerations. Failure to adhere to any of the basics mentioned above can result in losses. As many farmed species are highly sensitive to their environment, these losses can be substantial. It is essential that the management of the operation is appropriate for the specific species.

6.1.2 Key crop insurance issues

Key features of relevance to developing insurance plans are considered below. In Section 6.2 we review each of these issues for the two species under study in this report.

- **The size of the industry:** A small industry provides few opportunities to group risks or to spread risks across a wide range of industry participants. A small industry offers lower revenue opportunities for AIPs, especially if it is an industry in which they have relatively little experience and the costs of supporting the products are high.
- **The structure of the industry:** A heterogeneous industry also reduces the opportunity to spread risks among industry participants. This heterogeneity may be introduced by either differences in the nature of the production systems because of lack of regional concentration or differences in the engineering of production systems. Vertical integration may also be an important feature as vertically integrated companies have the ability to spread some risks along the links in the value chain that they own. A sector with highly concentrated ownership

could also be a difficult one for RMA to support given so few operations would benefit from the US government program.

- **The current and anticipated future status of the industry**: An industry under significant pressure and with poor prospects for growth is rarely a good candidate for a new risk management product. The opportunities for a profitable product are reduced and, if this is a new insurance market, the incentive to invest in support services is reduced. This is an important constraint if the industry is small and regionally dispersed.

- **The availability of price information:** If revenue insurance is to be provided, it is critical that an appropriate price is identified to serve as a base from which to measure liability and indemnity. The food products of aquaculture are sold in many forms (e.g. whole head-on, head off, fileted, fresh, on ice, frozen, live) and delivered to several different markets. It is essential that price data reflect the form in which the farmed product is sold and facilitate the calculation of the price at the farm gate (or possibly at a nearby processing location). These prices should be available consistently from a reliable and reputable source and they should be defined consistently over a suitable period.

- **Availability of production history:**

  - **The availability of data that identify the performance of a species in a particular production system:** These data should identify yields, losses, and cause of loss over a number of years. Data should be representative of species production in a particular system and should clearly identify the period of production (as production of some species extends over more than one year). To support sound rating and pricing it should reveal any differences among operations of different size, configuration, and location.

  - **The availability of data that indicate likely costs of production and revenue from the aquaculture enterprise:** The availability of cost of production and revenue information provides a basis for assessing the likely market size for an insurance product. Representative cost of production data will vary substantially among different farm configurations, locations, systems, and markets serviced. Representative data may be available where production of a species is regionally concentrated and where production systems are similar. In practice, this data is only available currently for catfish. Trout, the other important freshwater species with significant regional concentration has less reliable cost of production data as companies seek to protect their competitive position. Ideally, data on costs of production are required for each of the identifiable stages of production.

  - **The incidence of perils that might result in loss:** Data on the frequency of perils resulting in loss are required. These data are useful for the actuarial assessment of the insurance program, although it is only possible to isolate the impact of some perils. Final production is jointly determined by a host of different factors and the impact is captured in the farm enterprise production history.

  - **The extent to which risks of loss can be allocated to different stages of production:** The different stages of production may involve different levels of risk and clear classification of these stages may assist in developing different insurance coverage for each of these stages.

- **The perils that might result in loss**: These should be identified together with the management actions that might prevent or mitigate any loss. Those perils that influence the level of losses but cannot be prevented or controlled need to be carefully identified.

- **The ease with which the scale of losses can be identified:** Aquaculture losses occur within containment structures that contain water. This introduces serious challenges when identifying the inventory at any point in time and the scale of loss. Some systems are more amenable to assessment of losses than others are. Some perils result in more easily assessed losses than others. The method of loss assessment has to take account of the increase in biomass with time. In addition, movements in and out of the containment structure have to be measured and accounted for as well as deaths (normal mortality and culls), and escapes (in net cage systems). Finally, measurement of inventory and losses is challenging when multiyear production is a characteristic of the species and when mixing of batches occurs.

- **The perils must result in acute loss:** Fish are subject to many potential perils and some perils may impact performance only slightly. This results in major difficulties in assessing loss. Acute losses are more easily identified and measured than marginal losses.

- **The ease of determining the cause of loss:** As many losses may be the result of poor management practice, it is essential that the cause of loss can be accurately and rapidly determined and related to an insured peril.

- **The extent to which management affects the impact of perils and losses:** As noted above, management is a critical factor affecting the impact of various perils. Third party certification of good management practice is unavailable, although recently introduced schemes to certify responsible management are becoming more prevalent within the industry. However, this certification relates to practices that impact the environment and may preclude some practices that reduce losses (for example, the use of some fish health products).

- **The risk of moral hazard:** Moral hazard is a challenge in designing any crop insurance product. There are many potential sources of moral hazard to consider in developing aquaculture crop insurance. In particular, it is difficult to identify inventory and measure losses in aquaculture, and crop insurance policies must rely on farmers' own assessment of these. The risk of moral hazard in assessing the value of the loss is reduced by using publicly quoted and reliable price estimates. Other potential sources of moral hazard include misreporting of parameters such as initial stock, movements of production, feed use, and mortality or culling losses in support of the inventory assessment.

- **The risk of adverse selection:** The absence of comprehensive data that describe the population of aquaculture producers and their characteristics can result in a greater risk of adverse selection. Rating and pricing procedures based on poor quality or absent data might provide incentive for less proficient aquaculture managers to participate in an insurance plan with a view to collecting indemnities.

- **The availability of other risk management tools that might make an RMA plan redundant:**
  - A number of **federal or state funded emergency programs** may offer some compensation for losses. There have been several that have included specific losses to the aquaculture sector. Some **current RMA programs such as AGR-Lite** are available for aquaculture producers, although the various restrictions have limited use to a handful of operations. AGR or AGR-Lite is available for freshwater fish although AGR has a 35% livestock limitation that would preclude most aquacultural operations. AGR-Lite is not available in Arkansas, Louisiana or Mississippi, but is available in Alabama and Idaho. Various emergency measures have provided assistance to the aquaculture sector.
  - **Good management practice:** In addition, good management practice and sound design of the production system can reduce the risk of loss. For example, good management practice reduces stress and disease. Also, good management reduces the risk of electricity outage or disruption of the supply of oxygen by the purchase of generators and adequate backup stocks of essential inputs (such as oxygen, filters, critical pump accessories, etc.) and ensures disciplined application of biosecurity measures.
  - **Futures markets:** The only futures market available to handle price risk for aquaculture products is a Norwegian market trading salmon price indices. This market is largely used by North European salmon exporters and offer few hedging opportunities to the small US salmon industry.
  - **Other farm enterprises:** The risks associated with aquaculture production are also reduced if aquaculture represents a relatively small proportion of the total farm costs and revenue. This information is very difficult to establish for the aquaculture sector.
  - **The availability and use of private insurance:** Aquaculture insurance is available from private sources in several different countries for commodity species. The larger aquaculture operations can take advantage of private insurance provided on a business-by-business basis. However, many aquaculture operations producing species that have not been targeted by the international insurance industry have no private insurance available.
- **The likely level of demand and willingness to pay appropriate premiums:** The likely level of demand and willingness to pay is very difficult to assess. Of critical importance here is the level of premium in relation to the revenue of the enterprise and the cost of production, and the relative importance of aquaculture to the business. For much of aquaculture there are no relevant and representative cost of production and revenue data.
- **The definition of units of production:** In the previous review of aquaculture feasibility, a unit was defined as 'all the insurable containment structures of (the farm raised species) in the county in which you have a share on the date coverage begins for the crop year". This definition would seem appropriate for much of aquaculture production, although it might

need reconsideration in the case of marine net cage production of salmon as the definition of county boundaries in coastal locations might be questioned.

- **The availability of insurance industry expertise and resources to support an RMA plan for a specific species and production system:** Aquaculture insurance products may demand different types of support than agricultural or horticultural crop products. Reports of losses will require rapid attention to ensure that the cause of loss is adequately identified and linked to the level of loss. Appropriate cause of loss identification procedures must be available and results must be reported promptly. Loss measurement will require a new set of skills to interpret the relevant loss adjustment standards.

6.2 Summary of conclusions by species

The table below reviews each of these key crop insurance issues for the two species under review. We assess the extent to which each of the issues considered either constrains (✗) or supports (✓) the viability of a species plan. In some cases, it is difficult to provide a clear answer as some factors contribute to viability, and others do not. In these cases, the questions raised contribute to doubtful viability.

	Constraint
✗	**Major** – contributing to no viability
?	**Indeterminate** – contributing to doubtful viability
✓	**Minor** – suggesting viability

	Salmon	Shrimp	Comment
The size of the industry	✓	✗	Salmon is estimated to be the second most important farmed species in the United States with a 2010 value of $150 million. This value varies considerably with the fluctuations in the annual average market price. The value of shrimp production is estimated to be less than $10 million, less than half of the figure recorded in the 2005 Census of Aquaculture. This represents a very small sector □ only 9 of the 124 agriculture and horticultural crop categories identified in the Crop Values 2010 report issued by the National Agricultural Statistics Service (NASS), had a value of less than $10 million. There are several other species in saltwater aquaculture production in the United States but none have significant levels of production.
The structure of the industry	✗	✗	The ownership of the salmon industry is highly concentrated with only two international players operating all the farms off the coast of Maine and Washington. One of these is Canadian with operations in Canada, Chile, southern Europe and the United States. The other is a US-based venture capital company with seafood and aquaculture interests in various countries. The shrimp industry (five players in Texas, accounting for 85% of US production) comprises a very small number of operations with different levels of intensity of production and hence very different risks. In addition, there are a small number (we estimate 5 or 6 at most) operating shrimp production in RAS. RAS shrimp production has witnessed several business failures as investors have failed to identify the potential risks of this relatively new method of shrimp culture.
The current and anticipated future status of the industry	✓?	✗	Both shrimp and salmon are threatened by international competition. While they are both benefiting from relatively high current prices, the prospects of growth are limited, particularly in the shrimp sector, where basic cost competitiveness is poor compared with Asian producers in tropical areas.
The availability of price information	?✗	✗	Publicly available and reasonably representative price information is available for salmon, and shrimp. However, in both these cases, there are no publicly quoted prices for domestic production, although proxies are available for those products that are sold into commodity markets. There are regular published farmed salmon and shrimp prices published for all leading import origins. Some shrimp producers (both pond and RAS) sell into local markets for which there are no regular price quotations.
Availability of industrial production history	✗	✓?	There are only very broad brush industry level data describing production. In the case of the salmon industry, this data is assembled by the states of Washington and Maine. There are no data that describe the production record of individual units. As there are only two companies involved, these data are commercially sensitive. Some data are assembled to describe the Texas shrimp industry and its five pond-based participants. These reveal major farm differences in survivability. Other data suggest high pond performance variability and low survivability. There is no information on the reasons for these differences. Production history from shrimp raised in RAS systems is not available as this production system is relatively new and still at a developmental stage. No meaningful individual farm production history is available for salmon or shrimp to provide an indication of the variability in either production or mortality risk.
Availability of variability of individual performance or practices	✗	?✗	
The availability of representative data that identify the performance of a species in a particular production system	✓?	✗?	The limited number of salmon operators restricts the availability of data. Proxy data for salmon are available from other major Atlantic salmon production areas (e.g. British Columbia), although there are important differences between Pacific and Atlantic coast conditions. There are numerous reviews of salmon production in Norwegian fjords and in Scotland. There are some data available for shrimp from irregular academic studies and conference papers, although much of this is dated.

	Salmon	Shrimp	Comment
The availability of representative data that indicate likely costs of production and revenue from the aquaculture enterprise	✗	✗	There is poor availability of representative data on production costs and their variability by region or system. There are occasional academic studies that review these issues, but most are out of date. Most of these relate to production costs within a fairly narrow geographical boundary and are unlikely to be representative of national enterprise costs and revenues. In general, there is not the same intensity of study of aquaculture costs and revenues as might be found in crop agriculture
The availability of data that indicate the incidence of perils that might result in loss	✗	✗	The data on the incidence of major perils are regularly assembled by the insurance industry to cover catastrophic insurance (e.g. flood, drought, hurricane, tornado, and storm). Salmon and shrimp production farms are highly concentrated geographically and hence identification of serious weather events should be straightforward. However, the availability of published data that describe the incidence of other perils in aquaculture is absent for salmon and shrimp. Serious notifiable diseases (such as Infectious salmon anemia (ISA) for salmon and white spot disease (WSSV) for shrimp) that have resulted in devastating losses are documented although few academic studies have reviewed the incidence of other diseases and their losses for these two aquaculture sectors in the US. We have collected some of this information in the summary profiles of these species. Disease and parasites (often interrelated) represent the most important perils facing all species and all production systems in salmon culture in net cages, although predation from sea mammals is a constant threat. Various parasites (such as sea lice - Lepeophtheirus salmonis) are a major issue for salmon aquaculture. These infestations can seriously affect product value and have led to major controversy over the impact of farmed salmon on wild populations. Some diseases are highly infectious and unless appropriate precautions are taken they can be quickly transmitted among different containment structures on the same operation. Low levels of dissolved oxygen can be serious in pond shrimp production, but there is no systematic description of incidence.
The availability of data on normal mortality	✓	?✓	Estimates of normal mortality are available for salmon and shrimp from a number of academic and industry sources (10 to 15%). The estimates for US shrimp are available and indicate a very high level of mortality (around 50%). There are no supportable published data for shrimp in RAS, although anecdotal reports suggest these can be high. Most data refer only to the grow-out phase.
The extent to which risks of loss can be allocated to different stages of production	?	?	In general, stages of production can be identified, although there is little data that provides a representative view of the risks that impact production at these different stages. The production of eggs, fry, and smolts (the fingerling stage in salmon), and nauplii and post-larvae (the infant and juvenile stages of shrimp) involve the greatest losses of individuals. The grow-out period for salmon may also be represented by several different stages. As the stocking density of a net cage increases, fish of different sizes may need to be separated into other containment structures (although today in the US it is understood that the two farms are transitioning to a single class production system that does not involve movement between different production units). Mortality tends to be higher at the initial stages of grow-out when young fish and post-larvae are more vulnerable.
Knowledge of the perils that might result in loss	✓	✓	It is relatively easy for specialists in the field to arrive at a list of perils that can affect production at different stages for both species reviewed. However, there is little empirical data on the incidence of those perils. In addition to losses because of natural (weather-related) events, disease and parasites appear to be the most important perils affecting shrimp and salmon production.
The ease with which the size of the losses can be identified	?✓	✗	Various alternative methods of measuring inventory are used within the industry. In commercial salmon production inventory is measured regularly based on the counting of stock added (usually based on counts on loading of smolts from nurseries), mortalities, and regular sampling of size of fish. In addition, feed use and anticipated growth rates can be used to confirm inventory levels. While inventory measures are never claimed to be highly accurate, these methods are regularly used in reporting inventory levels as part of private insurance plans. As yet, there are no technological advances to improve the level of accuracy in counting fish, sizing fish, or measuring biomass. The challenge of measuring inventory and losses is particularly difficult in pond systems as management control and monitoring is far more difficult. Measuring inventory of shrimp farms is particularly difficult and currently there are no methods that can be applied with accuracy. RAS production of shrimp offers a better opportunity to measure inventory as tanks are usually fairly small and mortalities are

	Salmon	Shrimp	Comment
			normally identifiable. In all cases, detailed monitoring and recording of mortalities is required. Inventory assessment for shrimp is a very serious constraint on the development of a workable industry crop insurance plan.
The perils must result in acute loss	✓	✓	In general, losses that result from poor growth are difficult to assess and attribute during the grow-out period. Poor growth can result from a wide range of factors, most of which can be influenced by the quality of management, or the quality of the fingerlings or post-larvae. Perils that result in acute losses and mortality are more appropriately included in crop insurance plans. Both shrimp and salmon are subject to diseases that can inflict acute loss and high levels of mortality.
The ease of determining the cause of loss	?✓	?✓	As in any crop insurance plan, issues can arise over the precise cause of loss. For example, disease may impact production because an electricity outage stopped pumps from operating for a short period, resulting in deterioration in water quality and greater susceptibility to disease. Many diseases can be identified relatively easily, although some will need investigation by a reputable specialized analytical laboratory. In general, the US is well equipped with expertise to identify the leading shrimp and salmon diseases. Both salmon and shrimp are widely cultivated globally and more is understood about their culture than most other farmed aquatic animals.
The extent to which management affects the impact of perils and losses	✗	✗	While relatively small in international terms, the US salmon industry has the experience and capability to meet international standards of husbandry. In general, management can impact the incidence of a wide range of perils in salmon and shrimp, and in particular potential pest and disease risks. Good management practice will involve constant attention to the quality of the water medium in which fish or crustaceans are being grown. Poor management procedures can result in various disease issues, and constrain performance. The siting and physical configuration of an aquaculture operation influences the vulnerability to production risks such as disease. Sound organization and management requires investment in appropriate engineering and biosecurity measures to reduce the impact of perils and the potential for poor performance. In marine cage farming there is also the need to manage conditions within production areas or regions and for cooperation among neighboring farms. However, some diseases and water conditions are impossible to prevent. Operating in a marine environment reduces the control over the most critical production factor, the aqueous environment. Defining insurable perils in policies and underwriting documents represents a considerable challenge in aquaculture, especially where management actions play a key role, but even they may not be sufficient to prevent losses. The question that arises in the case of loss is 'Was enough done to prevent loss?' and 'can best management practice be defined to establish the limits of the marine finfish farmer's preventive actions'.
The risk of moral hazard	✗	✗	Because of the challenges in identifying the scale of loss, there is a high risk of moral hazard (particularly in the shrimp sector). Inventory assessments are extremely difficult to make and the insureds would need to maintain detailed records to confirm inventory at any point in the production cycle. Various mechanisms such as deductibles can reduce but not eliminate the risk of moral hazard. Practices such as movement of stock between containment structures or units of production, or delayed sales between calendar years complicate inventory reporting and measurement and raise moral hazard risk. The US salmon sector is well organized in terms of record keeping and familiar with insuring its stock. However, this is not the case for the shrimp industry where inventory measurement would be a serious challenge.
The risk of adverse selection	✗	✗	Because of the limited published data on the two sectors, it would be difficult to develop a rating structure that adequately reflects the diverse production risks. As a result, there is a risk of adverse selection should aquaculture insurance be offered (although the concept of adverse selection would appear redundant in the case of the US salmon industry with its two producers).
The availability of other risk management tools that might make an RMA plan redundant			See in rows below

	Salmon	Shrimp	Comment
A number of federal or state funded emergency programs	✓	✓	There have been several federal initiatives to assist agricultural producers as a result of disasters and all aquaculture producers can take advantage of NAP. We do not have access to data that will allow us to quantify the extent to which these programs are utilized. NAP provides catastrophic risk coverage of only 27.5% of the value of the crop, much less than would be provided by an RMA crop insurance program. While shrimp producers are eligible for NAP, we are unable to confirm whether offshore salmon farms can participate, although we suspect they can. APHIS has provided indemnities in the case of mandatory depopulation as a result of very infectious and serious diseases. This applied to an outbreak of infectious salmon anemia in Maine in 2001.
The importance of good management practice in reducing risks	✗	✗	There is a wide range of activities that might fall under the heading of good management practice that might reduce the level of risk. These include operational decisions (such as, for example, those that determine the quality of water, and the feeding regime); investment decisions (such as those that determine location and the configuration of the aquaculture facilities), and, more general organizational decisions (such as maintaining key equipment inventories, equipment maintenance and biosecurity - including the movement of staff, stock, and vehicles into the facility).
Availability of relevant futures markets	✗?	✗	There is one salmon futures market operating in Norway in local currency. This has minor relevance to risk management in the Atlantic salmon industry in the United States. Shrimp producers have no facility to manage price risks.
Other farm enterprises	?	?	Both salmon operations are large commercial companies with international interests and have diversified their production risks horizontally (through geography) and vertically (through hatchery, feed and trading operations). Some pond shrimp operations are vertically integrated with hatchery, processing and trading operations. There is no data describing the extent to which aquaculture activities are shared with other farm activities.
The availability and use of private insurance	✗	✓	Private mortality insurance is only available for species that are farmed in volume and where there is understanding of production practices and production experience. This is limited to Norway, Chile, Scotland, and parts of the Mediterranean, and the species Atlantic salmon and seabass/bream. In the US, Atlantic salmon producers are able to purchase private insurance that covers mortality. We have no information on the use of private insurance among RAS shrimp producers, although we understand that shrimp production globally is not insured because of the very high costs of gaining coverage.
The likely level of demand and willingness to pay appropriate premiums	✓	?✗	We understand that the salmon industry is concerned at the cost of private insurance, Most of the international farmed salmon sector buys private insurance. A major stimulus has been the insistence on mortality insurance as a condition of financing. Although we have no evidence, industry observers suggest that under its current financial conditions, US shrimp farms would be highly unlikely to pay the premiums necessary to cover for mortality insurance. These premiums would be high in recognition of the many challenges that face the supply of crop insurance to shrimp farmers.
The ease of defining units of production	✓	✓	In the previous review of aquaculture feasibility, a unit was defined as 'all the insurable containment structures of (the farm raised species) in the county in which you have a share on the date coverage begins for the crop year". This definition may involve considerable challenges when aggregating data from many diverse containment structures under the operation of one company within one county. This particularly applies to shrimp. This definition might need reconsideration in the case of marine net cage production of salmon as the definition of county boundaries in coastal locations might be questioned.

	Salmon	Shrimp	Comment
The availability of insurance industry expertise and resources to support an RMA plan for a specific species and production system	✗	✗	In general, the expertise of offering and supporting aquaculture insurance products within the United States is extremely limited. The market is relatively small, the data availability on the incidence and impact of perils is incomplete, and the costs of developing and supporting products and carrying out loss adjustment procedures are significant. This represents a major constraint on the feasibility of supplying RMA aquaculture crop insurance products. NAP has experience of administering catastrophic coverage. We understand that loss assessment represents a major challenge for that program, although we are unable to quantify NAP use in the industry. However, a very small number of local loss adjusters would be required for both salmon and shrimp as the industries are relatively small and regionally compact.

6.3 Concluding comments

An acceptable risk exists when:

- an actuarially sound premium rate can be determined and charged to customers who are willing to pay the price;
- customers cannot adversely select against the program;
- moral hazards are avoidable and controllable;
- there is enough interest for the risk to be spread over an acceptable number of insureds and geographic areas;
- effective loss controls are available; and
- perils are identified.

While the shrimp and salmon sectors faces many perils, several critical factors argue against RMA developing industry plans. These are listed below.

- The highly concentrated ownership of the **salmon** and **shrimp** sectors is inappropriate for an industry crop insurance plan. This restricts the spreading of risk over a sufficient number of insureds.
- The **salmon** industry is supplied by a well-established international private insurance sector.
- The small industry size of the **shrimp** sector suggests that there will be little incentive for AIPs to participate in the program.
- There are severe potential moral hazard and adverse selection challenges because of the high importance of good management practice in reducing the incidence of perils in **all species and systems**. This challenge is substantial in the case of **shrimp** production, and small in the case of **salmon**.
- •The highly diverse recirculating systems used in RAS shrimp production and the absence of sound statistical description of the character and experience of these systems poses serious challenges in actuarial analysis. These have widely varying degrees of effectiveness in controlling disease and mortality. Thus, any rating system would need to include type of RAS as a rating variable, but we do not have data that would allow it to be quantified.
- The challenge of measuring inventory and losses in **shrimp pond production systems** threatens the integrity of a crop insurance plan. Measurement of inventory is challenged by the absence of accurate biomass assessment or counting methods. Also, the lack of clear evidence of mortalities and cannibalism because of uneven stocking sizes or poor feeding, may frustrate accurate inventory measurement.
- Measurement systems that can be applied with some confidence are available for **salmon** in **net cages**.

- However, even these are challenged by multiyear production and the occasional practice of regularly moving **salmon** between different cages and units to maximize efficient carrying capacity.
- The studies reviewed and data collected suggest that the risk of loss in **pond shrimp** production in the US is very high. The lack of critical data (e.g. on prices (for US grown shrimp), causes of mortality, harvests, yields, losses, etc.) frustrates solid actuarial analysis and necessitates rates that could be higher than rates reflective of the true risk. This is likely to reduce **shrimp** industry participation.
- The lack of adequate data for sound actuarial analysis for **all species** could also lead to problems of adverse selection.
- There is little evidence to assist conclusions on willingness to pay, although we suspect that the shrimp industry in its current economic plight is unlikely to be a source of enthusiastic customers for policies with actuarially responsible rates.
- The cost of AIPs acquiring the necessary experience and skills to implement and administer these programs would be high and their interest in participation is likely to be very low.

Based on the above, we conclude that insurance plans meeting FCIC standards are not feasible and we recommend that the RMA does not pursue an industry crop insurance plan for any of the species we have reviewed.

APPENDIX 1. SOURCES OF AQUACULTURE FISH PRICES

Title: **Fulton's Fish Market Weekly Price, New York Frozen Prices**
Update frequency: Weekly
Data available from: 2005- present
Description: Currently selling prices ex-warehouse New York as reported by original receivers

- Shrimp peeled and undeveined - Gulf #5
- Shrimp headless, shell-on Gulf white and brown

Source: Fulton's Fish Market Daily Price Link
http://www.newfultonfishmarket.com/wholesale_price_reports.html

Title: **Fisheries of the United States**
Update frequency: Annual
Data available from: 1995- 2009
Description: Report on commercial and recreational fisheries of the US, including aquaculture estimates (volume and value) for catfish, salmon, striped bass, tilapia, trout and shrimp. Weights and values represent the final sales of products to processors and dealers.

- Estimated total annual production in pounds
- Estimated total annual value
- Manually calculated price per pound

Source: NOAA Fisheries Link
http://www.st.nmfs.noaa.gov/st1/publications.html

Title: **Urner Barry's Seafood Price Current**
Update frequency: Twice a week
Data available from:
Description:

- Farm-raised salmon, fresh, whole fish prices from West Coast
  - Sizes: 4-6lbs, 6-8lbs, 8-10lbs, 10-12lbs, 12-14lbs, 14-16lbs, 16-18lbs
- Farm-raised salmon, fresh, fillets, West Coast
  - Sizes: 1-2lbs, 2-3lbs, 3-4lbs, 4-5lbs

Source: Urner Barry, subscription required

Title: **Food and Agriculture Organization (FAO) Fishstat**
Update frequency: Annually
Data available from: 1950-2008
Description: Estimated production volume and value for salmon, catfish, giant river prawns, trout, hybrid striped bass, tilapia and shrimp, by country.
Source: Data from NOAA supplied to FAO is from the Census of Aquaculture and updated with estimates for years after 2005.

Title: **Farm-raised Atlantic Salmon Landings**
Update frequency: Annually
Data available: 1991-2010
Description: Number of whole pounds and value of farm-raised Atlantic salmon landings in Maine
Source: From 1992-2003 data were collected by the Finfish Aquaculture Monitoring Program, since then harvest totals have been submitted by leaseholders as part of annual or monthly inventory reports. Link http://www.maine.gov/dmr/aquaculture/HarvestData.htm

APPENDIX 2. AQUACULTURE PERMIT CHECKLIST FOR THE STATE OF WASHINGTON

Currently, in order to apply for a new aquatic lands lease from the Washington State Department of Natural Resources, a public or private entity must first pass several environmental reviews, and then obtain the necessary permits from the following regulatory agencies:

Agency / Reviewing body	Permit
Local governments	• Shoreline Substantial Development Permits, which review projects with respect to the Shoreline Management Act and also any local land use ordinances which may apply.
WA Department of Ecology	• Compliance with Shoreline Master Plans and Critical Area Ordinances. • Clean Water Act - NPDES Permits and/or Section 401 Permits. • Coastal Zone Management Certification
WA Department of Fish and Wildlife	• Hydraulics Project Approval Permit • Aquaculture license, and Transport Permits • Species Review Permit
US Army Corps of Engineers	• Section 404 and/or Section 10permits. • Review with respect to the Endangered Species Act (ESA)
US Fish and Wildlife Service and National Marine Fisheries Service	• Review of the project with respect to the ESA.

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