promar International

The feasibility of crop insurance for freshwater aquaculture

Contract number: D11PX18751

A report prepared for

Risk Management Agency, USDA

September 2011

Promar International
333 N. Fairfax Street, Suite 202
Alexandria, VA 22314 USA
Tel:(703) 739-9090
Fax:(703) 739-9098
E-mail: promar@promarinternational.com

The feasibility of crop insurance for freshwater aquaculture

A report prepared for

Risk Management Agency, USDA

CONTENTS

List of Figures

List of Tables

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 freshwater aquatic animals that are raised for food (tilapia, trout, catfish, hybrid striped bass, freshwater prawn, and largemouth bass). Some of these species are also raised for fee/recreational fishing and wild population stock enhancement (e.g. trout and largemouth bass).

- The substantial federal or state participation in native fish population enhancement activities distorts markets and frustrates valid assessments of the value of products. Consequently, the production of fry and fingerlings for this purpose is excluded from consideration.

- We excluded ornamental fish because production involves a very wide range of species and even less is known about the structure of the industry and the market than for other aquaculture sectors. Much of the industry operates informally, with very little description of production practices.

- We also excluded baitfish as this has been subject to intensive review in the earlier National Risk Management Feasibility Program for Aquaculture (NRMFPA) study. That review rejected baitfish because of the difficulty in adequately performing farm level loss adjustment, a lack of producer interest in insurance, and the absence of sound farm level market prices.

- In addition, we excluded consideration of the facilities stocking fish for sport in ponds (fee or recreational fishing). While this may represent an important farm enterprise, we considered that there were serious a priori challenges in respect to inventory assessment and loss measurement. Also, the boundaries of this sector are poorly defined as there is a lack of key statistical data.
- Hence, we review the feasibility of providing mortality insurance for the main species primarily farmed in the United States for use as food but with some production sold to those with recreational facilities (in the case of largemouth bass the primary focus is on recreational consumption).
- We rejected at an early stage the provision of insurance for poor quality product. Off-flavor issues are strongly influenced by farm management practices, as are problems with the appearance of the final product (including those resulting from diseases). 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. There is a very little recent information on the number of production units, their output, their yields, the systems of production, or market structure (e.g. regional, size, and ownership distribution and prices). The exceptions are catfish, and, to a lesser extent, trout, where regular statistical reports are prepared by USDA. In the case of the former, a detailed review of production practices has recently been completed by APHIS, and we have been able to review a prepublication draft.

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 substantial emphasis on supplying markets where premium prices are available, and where imported supplies cannot compete (e.g. local and live markets).
- The size of the industry producing the species under review has been contracting, although the commercial environment at the time of writing is boosted by relatively high prices for seafood products. All of the freshwater species sectors that we have reviewed are contracting with the possible exception of tilapia (where the officially reported data are acknowledged to be anecdotal).
- Where US aquaculture competes with commodity products (e.g. Atlantic salmon, shrimp, trout, catfish), the industry margins have been squeezed by the availability of imported

product. A number of new larger scale investments in recirculating aquaculture systems (RAS) systems involve species that are not candidates in this feasibility study. These are primarily single company industries (e.g. yellow perch and barramundi). Several of these species have an opportunity to develop niche markets, although, as yet, there are very few success stories.

- There are major constraints on the growth of the US aquaculture sector. In particular, the limited availability of good quality, farmable water, the regulatory framework, and lack of critical mass inhibit growth in the industry. Recent 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

- Of the species reviewed, catfish is by far the most important economically. In 2010, the annual farm gate value of output was roughly $400 million. The next most important species of the species reviewed are trout and tilapia (with a value of $63 and $53 million respectively), and hybrid striped bass (with a value of $30 million), followed by largemouth bass and freshwater prawns, each of which has a value of less than $10 million. Only 11 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 $15 million. There are several other species in aquaculture production in the United States, but no others have significant levels of production.

The structure of each industry varies considerably

- There are roughly 900 catfish producers and 320 trout producers in United States. There were roughly 130 tilapia producers recorded in 2005, although today there are reported to be between 30 and 40 operating on a commercial scale. Between 60 and 70 producers grow hybrid striped bass, although only 25 of these are reported to be of commercial significance. Roughly 80 producers of freshwater prawn were identified in the 2005 Census of Aquaculture, although there is considerable uncertainty about the numbers today - some say possibly three times that number, with many operating on a very small scale.
- The trout industry is highly concentrated in Idaho where three larger companies dominate the raceway production of trout for food production and one probably represents 40 to 50% of total US production. However, there are many smaller operations producing trout in raceways throughout the nation. The hybrid striped bass industry includes a small number of very large specialist farmers, although smaller operations are dispersed through several states. Of the 30 to 40 commercial tilapia farms, one produces 20 to 25% of sector output. The catfish industry comprises small and medium-size companies with relatively little concentration of ownership. The largemouth bass and freshwater prawn sectors include only relatively small-scale operations.

Four main production systems with very different character

- Trout are produced in raceways, tanks, net cages, and ponds, although the latter are largely used for recreational purposes and most commercial systems are based on raceways. Tilapia is largely produced in recirculating systems, although a small proportion of the output is grown in ponds. 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. Catfish, hybrid striped bass, largemouth bass, and freshwater prawns are mainly grown in ponds. Pond systems tend to be much cheaper to operate, largely because of the lower investment costs required. Recirculating systems are the most expensive 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 fish and dispose of 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 in more northern locations.

Production systems have different types of risk

- With the exception of RAS, there are limited opportunities to control growing conditions in most production systems. 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 also a problem with pond production as protective netting is more expensive to install and not always effective. A recent survey of catfish growers suggested predation was the most prevalent peril event, and we suspect that this is the case for all species grown in ponds. This survey also identified only limited monitoring of water quality, continuous introduction of fingerlings (multi-batch production), the sharing of ponds with other species, and very little use of fish health products that can combat two major disease perils. While this survey related to catfish production, some of the characteristics may hold for other species raised in ponds.

- Raceways are continuously replenished, and incoming water will provide oxygen and outgoing water removes metabolic and solid wastes. Underground water sources are associated with consistent temperature and quality, although many units use springs, streams or other surface water. Stock numbers and condition can be more easily monitored in raceways, although movements between raceways and between facilities are common as a method of managing efficient carrying capacity of different raceways.

- 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 greater 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.

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. 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. Drought has been an important occasional peril in a number of states where aquaculture is practiced. Threats to water sources because of excess demand are potentially more serious as they may threaten the longer-term position of aquaculture in a given region. Flooding is also a peril associated with 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, most of which are related to human activity.
- Data is available up to 2008 on industry losses for trout from the National Agricultural Statistics Service. These data reveal that disease is by far the most important cause of loss (70% of the volume losses), followed by drought and predators. These perils varied substantially by region, although the data assembled from this source cannot be analyzed to extract direct state comparisons. A recently available study of catfish indicated that production and some bacterial diseases were the most common loss, although depleted dissolved oxygen supplies resulted in the highest losses. This is likely to be the conclusion for all pond aquaculture. Disease is a major peril for all species in all production systems.

Disease

- Many bacterial disease and parasite threats are common to different production systems and species, although the susceptibility of different species may vary. Fungal and viral diseases may also be important, although these tend to be more critical for individual species. 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. Disease outbreaks are often linked with high levels of stress in aquatic animals because of poor management of water quality, crowding, or inappropriate feed.

- Aquaculturalists 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, serious, bacterial diseases are extremely difficult to dislodge, and the only solution is to fallow and disinfect a containment structure and treat it to remove the cause of the disease. In general, with fixed 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 or reservoir 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 NRMFPA study reviewed the crop insurance feasibility for catfish, trout, baitfish and salmon (the latter 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 covering yield verification, inventory measurement, and disease spread, a large-scale risk management survey of aquaculture producers, a review of private sector insurance, listening sessions, and separate workshops with actuarial practitioners, aquaculture production specialists and trout and catfish farmers. The research program was accompanied by detailed actuarial analysis based upon data collected in the cross-sectional survey and also historical data collected by USDA on trout and catfish. The program involved collaboration among university aquaculture departments, extension workers, and representatives of the different species industries. The RMA staff recommended against proceeding with either draft policy, and that recommendation was endorsed by the Board of the FCIC.

Our approach

- Our feasibility reviews the materials and focuses on some of the key issues identified in the previous study. Our approach is based around 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:

- Catfish would appear to have a structure which is amenable to the development of the crop insurance program. The sector is geographically concentrated, systems of production are similar, all being based on ponds, and all production is destined for food production. Trout is much more geographically diverse, although most production is conducted in raceways. While most trout production is destined for food use, some production is for recreational use or restocking public and private waters. The industry in Idaho (representing roughly 70 to 75% of total production) is characterized by high levels of concentration of ownership. Tilapia companies are mainly using RAS, although there is some pond production in southern states. Tilapia production is widely distributed throughout the country, although a small number of larger companies supply a large and increasing share of the market. While most farms supply the live market, the configuration and engineering of these facilities varies considerably. The production of hybrid striped bass for food is concentrated in Texas among a relatively small number of specialist growers; however, the species is also raised in many other states. The freshwater prawn sector is dominated by small-scale operators, most of whom sell their product from their farms.

- Industry size and/or structure considerations raise challenges for RMA industry insurance plans for freshwater prawns, largemouth bass, tilapia, trout, and hybrid striped bass. Catfish has an amenable structure for crop insurance. The trout and tilapia industries are particularly diverse; consequently, there are major challenges in identifying different risk pools.

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 all species reviewed. However, as noted above, apart from catfish, there is little empirical data on the incidence of those perils. Disease and parasites appear to be the most important perils affecting aquaculture production, although predation and loss of dissolved oxygen can be major issues in pond systems.

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. Perils that result in acute losses are more appropriately included in crop insurance plans. All reviewed species 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. The limited availability of this independent specialization and expertise on a national basis would be a cause of concern for insuring some species. It is worth underlining here that aquaculture is a relatively new commercial activity, especially when undertaken on an intensive basis. There is not the same body of knowledge available compared with animal agriculture or crop production. This applies to key supporting sciences such as genetics and breeding, physiology, fish health, nutrition, etc. The gradual development of a firm scientific understanding will eventually lead to more precise and accurate identification of cause of loss in each of the species under review.

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

- In general, management can impact the incidence of a wide range of perils in all reviewed species, 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 are being grown. Poor management procedures can result in various disease issues, and constrain performance. The 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.

Measurability

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

- Various alternative methods of measuring inventory are used within the industry. Most of these are associated with relatively high levels of error. As yet, no technological advances 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. These difficulties are amplified by practices such as multiple batch production and stocking ponds with other species. Finally, there may be a lack of clear evidence of mortality (e.g. when dead fish sink rather than float, or as a result of cannibalism). Raceways, RAS and net cages offer better opportunities to measure inventory, although detailed record keeping is required. Even then, close observation and recording of a loss event is required. Consequently, inventory assessment is easier for trout produced in raceways, tilapia in recirculating systems, and trout when in net cages. Inventory assessment for the other species reviewed 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 only available for catfish. There are no regularly and consistently reported sources of price data for hybrid striped bass, freshwater prawns, live largemouth bass, or live tilapia.

Availability of production history:

- Industry level production history is available for trout and catfish from regular documentation of the industry over an extended period. However, these data do not describe some key characteristics of the industry nor do they describe the variability in individual performance. Most major trout and catfish farms involved in food production are likely to have good records of fish introduced, fish harvested, and feed consumed. Production history from tilapia farms is likely to be available as RAS demands careful monitoring of inputs and outputs. Data for the other species is likely to be available although some less formal operations are unlikely to maintain an adequate level of record-keeping for crop insurance purposes. This is particularly true of freshwater prawns where production is mainly sold at pond side. No individual farm production history is available for any species 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:

- In general, catfish and trout have data that provide some indication of yields, although many of these data are not available by state because of confidentiality restrictions. For all other species, basic industry data on production levels, etc., is compiled anecdotally. There is some data available for the other species from irregular academic studies although much of this is dated. The hybrid striped bass sector is subject to a regular annual survey of leading producers and state aquaculture observers.

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. Some species associations (e.g. the hybrid striped bass association) provide estimates of costs and revenues on either an annual or an irregular basis. These are not assessed on a formal and systematic basis. 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). However, the availability of data that describe the incidence of these and other perils in aquaculture is limited for most species, although occasional academic studies have reviewed the status of individual sectors. Trout and catfish are subject to regular collection of data, and these data provide a broad picture of the most important perils. Critical detail (e.g. the specific disease peril and its impact) has been absent although a soon-to-be published report on catfish production practices provides useful data on mortality events. We have collected some of this information in the profiles of different species. The evidence suggests that disease and parasites (often interrelated) represent the most important perils facing all species and all production systems in aquaculture, although predation is a major issue for pond systems. Some diseases are highly infectious and unless appropriate precautions are taken they can be quickly transmitted among different containment structures on the same operation. Drought and flood have relatively low incidence (at least as identified for catfish and trout where empirical data are available), although their impact is regionally concentrated and may be serious in any given year (such as 2011 for catfish). However, long term drought and the growth in water demand are seriously threatening water supplies in several regions.

The availability of data on normal mortality:

- Estimates of normal mortality are available for all species from a number of academic and industry sources. However, there is likely to be substantial variation by species, production system, and location. Most data refer 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 fingerlings involve the greatest losses of individuals (this varies by species, but may be a high proportion of the original population). The grow-out period may also be represented by several different stages. As the density of production increases, fish of different sizes may need to be separated into other containment structures. Mortality tends to be higher at the initial stages of grow-out when young fish 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 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. APHIS has provided indemnities in the case of mandatory depopulation as a result of very infectious and serious diseases.

Availability of relevant futures markets:

- There is little opportunity for the producers of any species to handle price risk through hedging on futures markets or through the limited prospect of fixed price sales on contract to processors.

Other farm enterprises:

- There are no data describing the extent to which aquaculture activities are shared with other farm activities. It is feasible for aquaculture conducted under any production system to be incorporated into an existing farm business. Some aquaculture producers are vertically integrated to some extent, providing some opportunity to handle risks at the production stage with other activities (e.g. trout in Idaho). This is more likely to be available to the larger producers.

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 addition, a small number of larger scale RAS enterprises that are funded by banks or private equity funds are required to seek insurance as a condition of financing. This is provided by brokers operating through the small number of foreign insurance companies that have some expertise in the aquaculture sector. However, this insurance cover is expensive. The cost reflects the high risk, in addition to the insurance industry's relatively little experience of these species and these types of operations in the US.

Other issues

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

- There is no information available on the likely level of demand and willingness to pay for insurance. In general, there has not been an intensive effort to seek out crop insurance by any of the participants in the industry. When the proposals for catfish and trout plans were rejected by the FCIC Board there appears to have been little industry reaction through their associations. Few in the industry are aware of the initiative in the last Farm Bill that resulted in this study. The larger companies involved in trout production consider it too expensive and do not participate. The major stimulus for insurance has been the involvement of parties offering finance to aquaculture companies. With the exception of the larger RAS investments, traditional finance for aquaculture is supplied by the leading companies providing aquafeeds, or by the growers themselves. Feed companies have not insisted on crop insurance.

The risk of moral hazard:

- Because of the challenges in identifying the scale of loss, there is a high risk of moral hazard. 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 continuous stocking, movement of stock between containment structures, or delayed sales between calendar years complicate inventory reporting and measurement and raise moral hazard risk. Some sections of the species industries reviewed are well organized in terms of record keeping. However, it would be difficult to identify these in developing the appropriate underwriting or rating structures.

The risk of adverse selection:

- As data on the aquaculture sector are very limited, there is a high risk of adverse selection when offering aquaculture insurance. This risk is reduced in sectors such as catfish where production is regionally concentrated and production systems are similar. While there is much data available on the trout sector, the production is fairly widely distributed geographically and there is insufficient data on production in different regions to facilitate the identification of risk pools. The risk of adverse selection is much higher in all of the other species sectors as adequate descriptive data are not available.

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 country.

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 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.

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 aquaculture sector faces many perils, several critical factors argue against RMA developing industry plans. These are listed below:

- The small industry size for **freshwater prawns** and **largemouth bass** grown for food suggests that there will be little incentive for AIPs to participate in the program.
- There are severe serious 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**.
- The highly diverse **recirculating systems** used in **tilapia** production and 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.
- The challenge of measuring inventory and losses in **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, and the occasional application of certain practices in some species and on some operations. These practices include: continuous stocking of grow-out ponds; the use of other species for under-stocking; the movement of stock between ponds and/or facilities. Also, the lack of clear evidence of mortalities; cannibalism because of uneven stocking sizes or poor feeding; and, the mixing of different batches, may frustrate accurate inventory measurement.
- Measurement systems that can be applied with some confidence are available for some **trout** facilities in **raceway systems**. However, even these are challenged by multiyear production

and the occasional practice of regularly moving **trout** between different raceways and facilities to maximize efficient carrying capacity.

- In the **tilapia**, **hybrid striped bass**, and **trout** sectors, the number of commercial operations is relatively small with a significant share of industry output in the hands of a few companies. This restricts the spreading of risk over a sufficient number of insureds.
- The availability and use of private insurance for some larger **RAS** investments implies that provision of crop insurance is already available to some in sectors using this system.
- The lack of critical data (e.g. on prices, causes of mortality, harvests, yields, losses, etc.) that frustrates solid actuarial analysis for **all species** necessitates rates that are likely to be far too high to result in industry participation.
- The lack of adequate data for sound actuarial analysis for **all species** could also lead to problems of adverse selection.
- While there is little evidence to assist conclusions on willingness to pay, **no species** sector is the pushing hard for crop insurance coverage.
- 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.

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 freshwater species, including but not limited to (i) catfish (*Icataluridae*); (ii) rainbow trout (*Oncorhynchus mykiss*); (iii) largemouth bass (*Micropterus salmoides)*; (iv) striped bass (*Morone saxatilis*); (v) bream (*Abramis brama*); (vii) tilapia (*Oreochromis niloticus*) and shrimp (*Penaeus*). All except shrimp were reviewed. Shrimp was excluded as the primary relevant farmed shrimp is *Litopenaeus vannamei, (*formerly classified as *Penaeus vannamei*) and this is not farmed in freshwater. This species was replaced in the review by the giant river prawn (*Macrobrachium rosenbergii*).

Our research revealed that bream is not farmed in the United States and consequently we have nothing to report on this species. Also, our research on striped bass aquaculture revealed that all production for food is hybrid striped bass – based on crosses of *Morone saxatilis* and *Morone chrysops*. We reviewed the feasibility of crop insurance for the culture of that hybrid.

This report covers the freshwater 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 aquaculture for wild stock enhancement or for ornamental purposes. The enhancement of fish populations in lakes, rivers, streams, reservoirs, and oceans involves considerable non-private involvement. Federal, state, and local authorities invest in hatcheries and egg and fingerling production facilities to maintain populations. As a result, the production is subsidized and markets are distorted. The farming of ornamental species involves a very wide range of species and very little is known about the structure of the industry and the nature of the market. Much of the industry operates informally, with very little description of production practices and procedures.

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.

In addition, we excluded consideration of the facilities stocking fish for sport in ponds (fee or recreational fishing). While this may represent an important farm enterprise, we considered that there were serious a priori challenges in respect to inventory assessment and loss measurement. Also, the boundaries of this sector are poorly defined as there is a serious lack of key statistical data.

There is considerable overlap in the farming of fish for food and for recreational purposes, and this creates the potential for confusion. The 2005 Census of Aquaculture illustrated that fish raised for food (referred to as food fish in the census) could also be sold for feed and recreational fishing[1]. Similarly, sport or game fish raised in aquaculture could be sold for food. While less than 5% of food fish were sold for fee or recreational fishing in 2005, it is difficult to assess the proportion of sport fish sold for food. Five per cent of sport fish were reported as sold to processors, 28% to consumers, and 41% to wholesalers/brokers. In general, there is some overlap between sales for food and recreational purposes and this cannot be disentangled by the statistical data available on the sector. One of the species subject to review is largemouth bass. This species is primarily sold for recreational purposes, but it also is sold live into consumer markets. Trout is primarily sold for food but is also sold for stocking ponds for recreational fishing.

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.

[1] See section 14 of 2005 Census of Aquaculture data collection instrument.

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 considerably 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 some of the species and production systems 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 (trout and catfish). These reviews were prepared by experts that participated in the preparation of the original species profiles for the NRMFPA.
- The development of summary species profiles for tilapia, hybrid striped bass, largemouth bass, and freshwater prawn. 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. These 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. 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 on the NRMFPA

Many of these issues were reviewed in the NRMFPA. This program was 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.

(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)[2],
  - 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),

[2] 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 and salmon.

- 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)
- 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 all species and aquaculture systems was provided by John Forster, Port Angeles, WA. Information was obtained from many individuals but assistance on the production of the species under review and various production and market issues was received from the following.

- Michael Timmons, Professor of Department of Biological and Environmental Engineering, College of Agriculture and Life Sciences, Department of Biological and Environmental Engineering, Cornell University. (Recirculating systems and tilapia)
- James Tidwell, Professor/Chair, Division of Aquaculture, Aquaculture Research Center, Kentucky State University (Freshwater prawns and largemouth bass)
- Marc Turano, Mariculture and Blue Crab Specialist, North Carolina Sea Grant, (Hybrid striped bass)
- Stephen A. Smith, Professor, Biomedical Sciences and Pathobiology, Virginia-Maryland Regional College of Veterinary Medicine, Virginia Tech (Aquatic animal diseases)
- Granvil Treece, Aquaculture Specialist, Texas Sea Grant College Program, (Aquaculture systems)
- Bill Varano, American Tilapia Association, (Tilapia)
- Mike Frinsko, Area Aquaculture Agent, Jones Co. North Carolina State Aquaculture Extension Office, (Tilapia, Hybrid striped bass)
- Harry Daniels, Extension Aquaculture Specialist, North Carolina State University, Zoology Department. (Hybrid striped Bass),
- David Albaum, Evergreen Insurance, (Aquaculture insurance)
- Ruth Francis Floyd, Department of Fisheries and Aquatic Sciences (Institute of Food and Agricultural Sciences), University of Florida (Aquatic animal diseases)
- Steven Summerfelt (Recirculating Aquaculture Systems), Director of Aquaculture Systems Research, The Conservation Fund's Freshwater Institute, West Virginia.
- Gary Fornshell, Extension Aquaculture Educator,University of Idaho. (Trout)
- Carole Engle, Director, Aquaculture/Fisheries Center, Department of Aquaculture and Fisheries, Professor, Aquaculture Economics and Marketing, University of Arkansas at Pine Bluff. (Catfish)

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. 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. The countries of 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 crustaceans, and Asia produced 88% (Table 1).

2.1.1 Global production

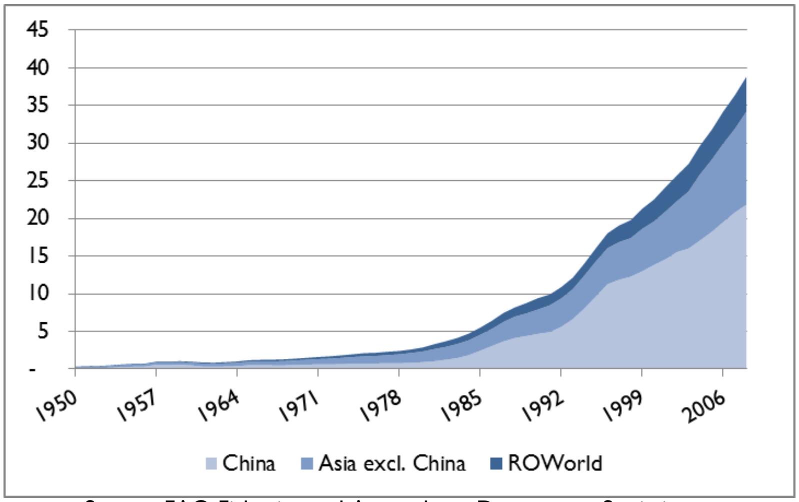
Capture fisheries and all aquaculture production are shown in Figure 2. It will be seen that total production is growing, although that growth is generated by aquaculture. The output from capture fisheries has leveled off in recent years.

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%

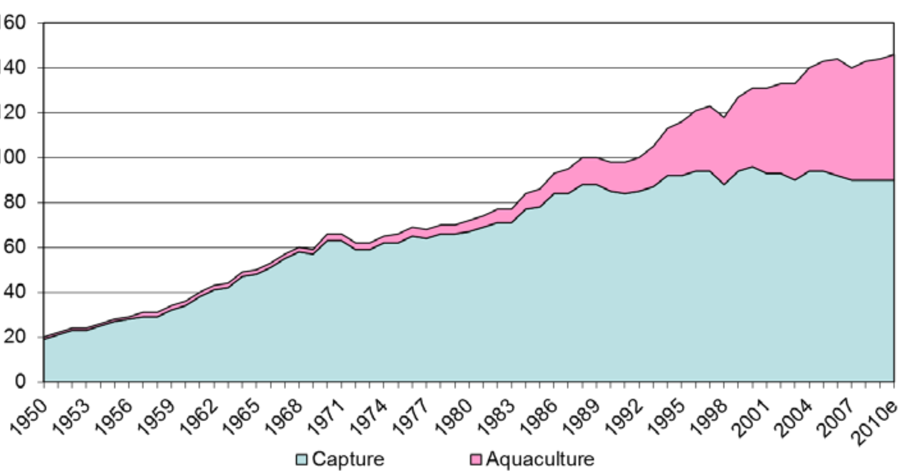
Source: FAO Fisheries and Aquaculture Department Statistics

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



Source: FAO Fisheries and Aquaculture Department Statistics

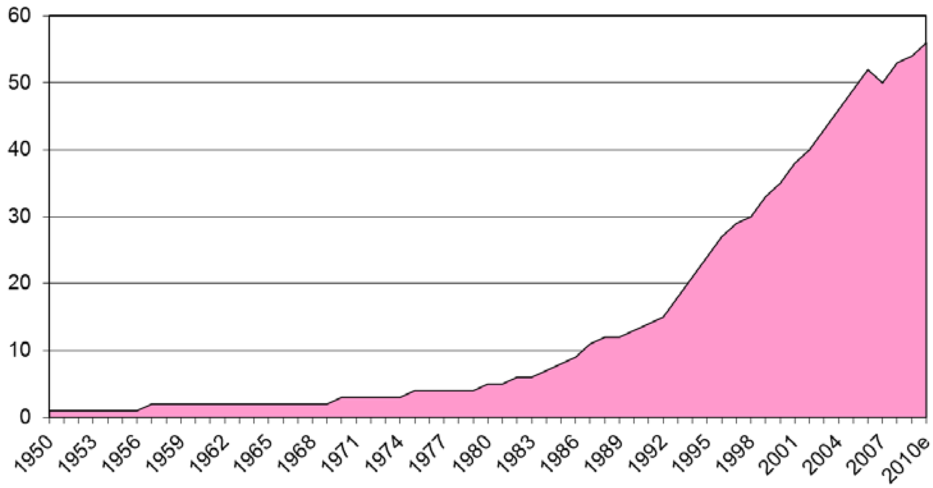
Figure 2: Development of capture and aquaculture output (million MT)



Source: FAO FishStat aquaculture database

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

Figure 3: Development of all aquaculture output (million MT)

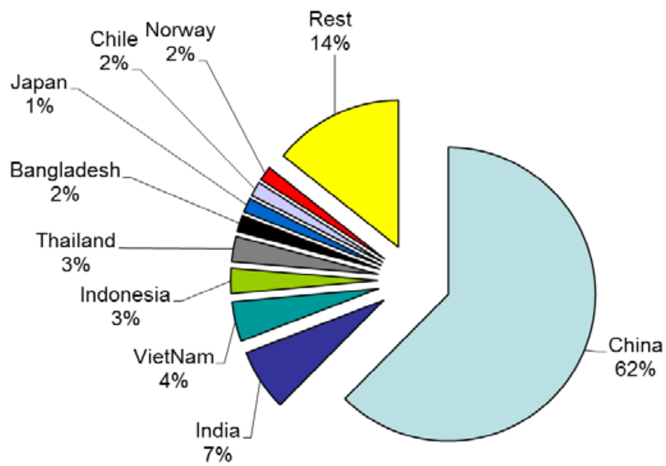


e = provisional
Source: FAO FishStat aquaculture database

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.

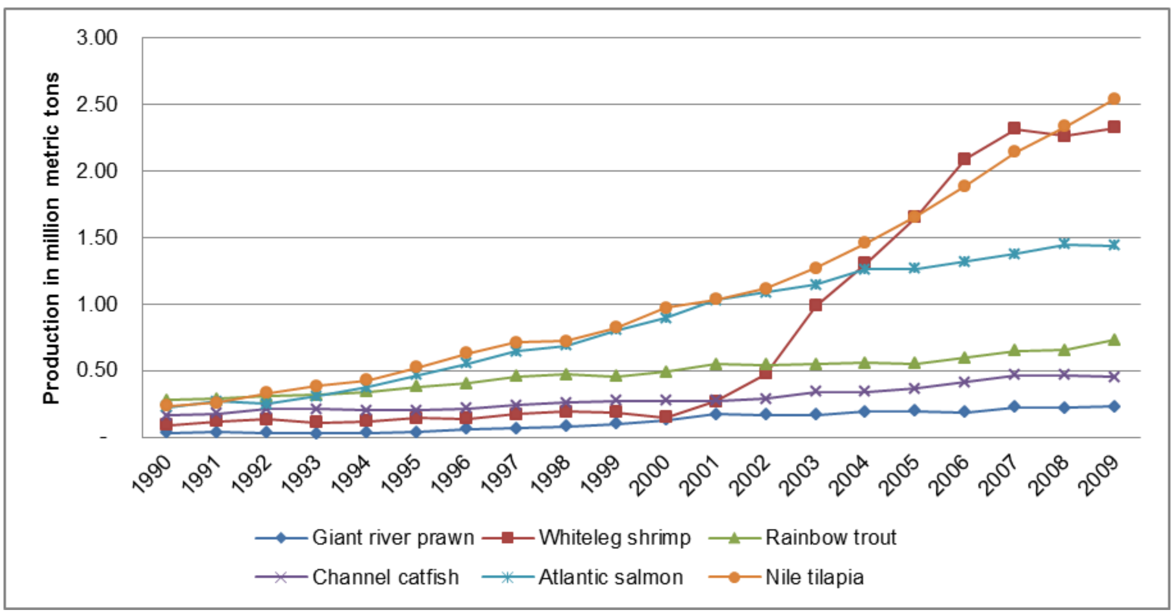
Figure 4: Share of aquaculture production, 2008



Source: FAO FishStat aquaculture database

The growth in aquaculture production of the species under review is shown in Figure 5. The two main saltwater 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 FishStat aquaculture database

2.1.2 US production

US production of the species we are reviewing is illustrated in Table 2. The two main saltwater species (salmon and shrimp) 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] 12 [e]	29 [d] 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 [k]
Shrimp (food-size)	8 [d]	18.6 [d]	3 [i]	7.2 [i]

Sources:

a. Hanson (2009 US catfish database)
b. NASS (Catfish & 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.

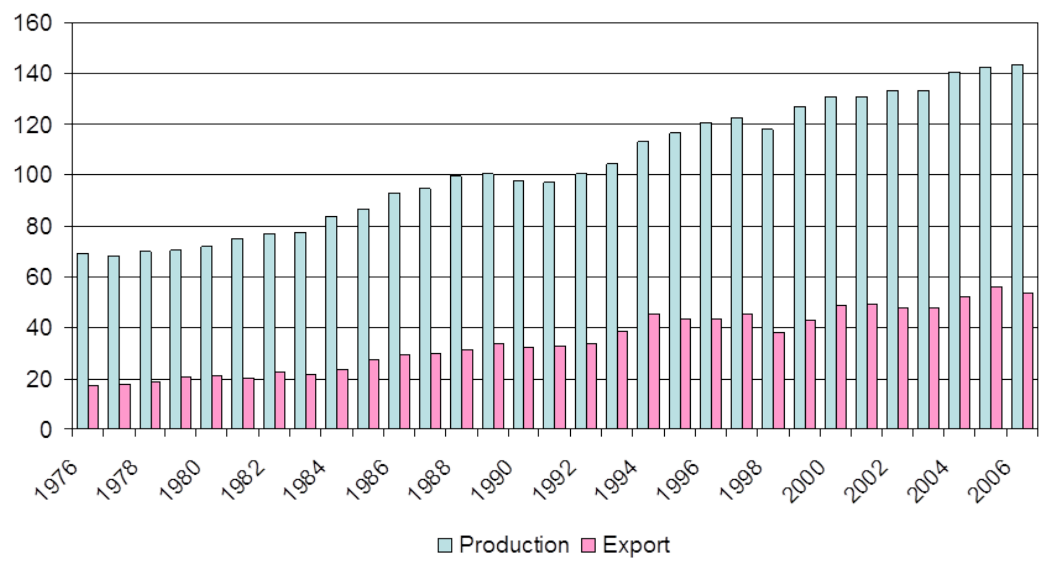
Even as the amount of fish consumed continued to rise, it still represents a very small share of total animal protein consumed in regions of the world such as Oceania, Europe and North America. When measured in terms of the intake of animal protein FAO estimates it varies from 6.2 grams per capita per 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.

In 2007, developing countries consumed 15.1 kg of fish per annum and low-income food-deficit countries consumed 14.4 kg per annum. In these low-income food-deficit countries representing approximately 1.5 billion people, fish accounted for more than 20% of animal protein consumed and this number is believed to be underestimating fish consumption because many subsistence fisheries' records are not reported.

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 market. 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

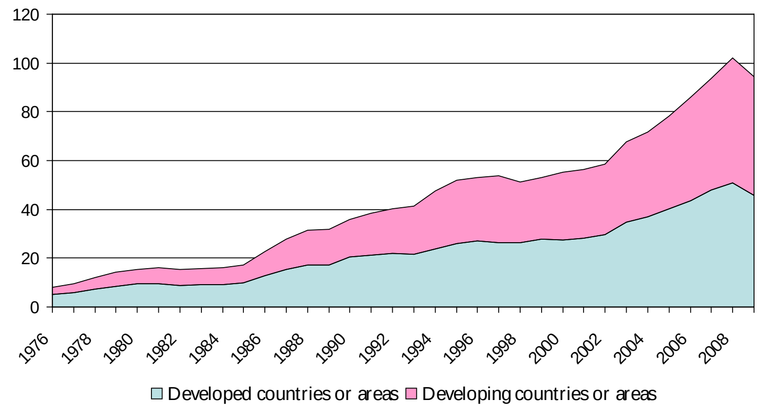


Source: FAO Fisheries and Aquaculture Department Statistics

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.

The largest exporters of aquaculture products are China, Norway (primarily 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 it 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 technology that is more sophisticated 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 products in some retail and food service outlets. These tend to be serviced by specialist distributors and these 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.

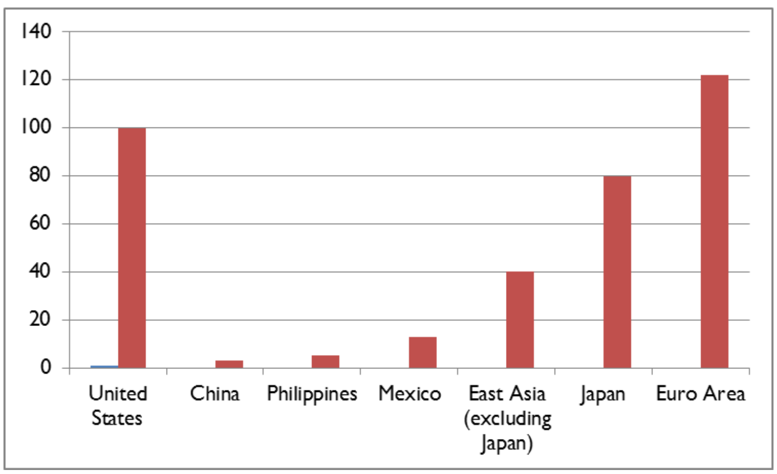
2.1.6 Asia dominates sub-tropical and tropical aquaculture production

Catfish, shrimp, and tilapia are highly competitive commodity markets. China is a major supplier of tilapia to the North American, Central American, and Caribbean markets, and Southeastern Asian sources dominate the supply of catfish and shrimp. 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 has developed substantial export-oriented sectors.

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 processing which is more labor intensive. 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/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 because 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[3] is a key component in the costs of production and this will vary depending on species. For most of the species under review, the US has available ample supplies of good quality starting stock. Major players have made investments to breed improved strains and to develop their own hatcheries to maintain high levels of biosecurity.
- Some leading aquaculture production countries have benefited from the advantages of scale and geographical concentration. They 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: Many issues could affect the rate of growth. It is likely that environmental pressures will grow, and there is evidence that producers will respond to the demands of their customers by seeking participation in the various schemes that certify responsible management.

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.

3 The nauplius and post-larvae stages are the larval and immediate post larval phases of crustacean development.

Technical advances: There are still major technical breakthroughs to anticipate in terms of the production of shrimp, tilapia, catfish, and many other 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, many species 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 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.[4] 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).

[4] 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.

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 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.

Regulations are not consistent among states and compliance with these regulations involves a wide range of county and state agencies, in addition to the three federal agencies mentioned above. 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.

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.[5] 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.

---

5 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.

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. 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.

Because of the competition, much of US aquaculture production is destined for niche markets that cannot be easily reached by imported product. For example, a large proportion of the output from US aquaculture (for species such as tilapia) serves live seafood markets in major metropolitan areas. 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 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 on seafood. This growing demand and the constraint on a matching production response hold 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 warrants investigation that is more detailed. Many factors could intervene to continue to pressure US fish and crustacean farm margins.

While environmentally friendly RAS raise considerable media attention, they are an expensive method for producing fish. RAS was featured on a very recent Time magazine cover under the headline 'The end of the line'.[6] This article focused on Australis's Massachusetts-based RAS for barramundi, much lauded for its environmental merits and, apparently serving a healthy niche market in upscale retail and food service. However, the article contained these telling quotes.

> *"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].*

6 http://www.time.com/time/health/article/0,8599,2081796,00.html

> *"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.[7]

> ***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.*

7 Waterlines, Winter 2010, Aquafish collaborative research support program, USAID/Oregon State University,

SECTION 3: AQUACULTURE SYSTEMS

3.1 Ponds

Pond culture is the most common type of commercial aquaculture in the US. In 2005, according to the Census of Aquaculture of that year, 64% of farms selling aquaculture products had ponds. Their versatility allows for a range of production intensities and species, including bottom dwelling species like freshwater prawns. Ponds do not 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.

Site selection is critical. While most pond aquaculture does not require access to large volumes of flowing water, some method of replenishment is required. 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 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 PL, 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 freshwater system for catfish, hybrid striped bass, largemouth bass, and freshwater prawns. They are also used for tilapia production, although most 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 freshwater prawns.
- 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.

3.2 Raceways

The Census of aquaculture recorded 11% of farms selling aquaculture products in 2005 had flow-through systems such as raceways. Raceway systems comprise long, narrow containment structures that water passes through. This system carries a continuous supply of water, which enables producers to stock fish in higher densities. In most systems gravity pushes stream or spring water through the system, however pumps and underground water can be used. Pumping adds significant costs to the operation and it is usually avoided. The continuous movement of water flushes waste products from the raceways, maintains good water quality, and promotes healthy conditions. Since pumping is expensive, raceway aquaculture is limited to freshwater species.

An advantage of this system is that fish can be stocked in higher densities because the species grown in this system use the entire water column and the constant supply of high-quality water will support more fish. The channel design of raceways enables producers to assess inventory levels with relative ease. This is critical to ensure that feed rates are appropriate for the number and size of fish. The monitoring of the carrying capacity of any given raceway is critical to efficient production. When the maximum carrying capacity is reached, it is normal for fish to be graded and moved to raceways with available capacity. Fish may be moved two or three times during a production cycle.

High-density operations require careful monitoring of water quality. The dissolved oxygen rate will be controlled by the rate of water flowing through the system, which can vary. Therefore, the stock density and feed input rate must be adjusted to make sure the dissolved oxygen concentrations do not fall and cause unnecessary stress on the fish. Even with a sufficient water flow, care must be taken to ensure that raceways are clean to avoid susceptibility to disease or parasites. Disease control involves the use of medicated feed and ensuring that healthy stock is introduced into raceways.

Since raceways require large quantities of water there will be a lot of discharged water. Water discharge is regulated by federal, state, and local laws and farm facilities may need to invest in water treatment before discharge. As nitrogen and phosphorus are excreted as waste from digested food, care must be taken to develop husbandry systems that retain these nutrients or use effluent treatment that reduces the nutrient load in any water discharge. The use of FDA approved medicated feeds must be approved and regulated by the EPA's Concentrated Aquatic Animal Production (CAAP) regulations, which are described in Section 2.2.1.

Many species can grow in raceway systems. The most common in the United States is rainbow trout, and nearly all trout culture for food production takes place in these systems.

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

Advantages

- Do not require large land area.
- Close control of water quality and stock possible.
- Well suited to fish that use all the water column.
- Stock monitoring is less difficult than in ponds.

Disadvantages

- Require large volumes of flowing water and a receiving watercourse into which to discharge used water.
- Free (gravity) flowing sources of water are rare. Pumping is costly.
- There are no gravity fed options for saltwater.
- All feed must be provided from outside sources.

3.3 Cages or net cages

The Census of Aquaculture in 2005, identified 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. Net pens are used mainly by commercial salmon operations, although there is a minor use in trout production.

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 freshwater prawns.
- Stock monitoring is more difficult than in raceways, but less so than in ponds.

3.4 Recirculating systems[8]

In 2005, The Census of Aquaculture recorded 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.

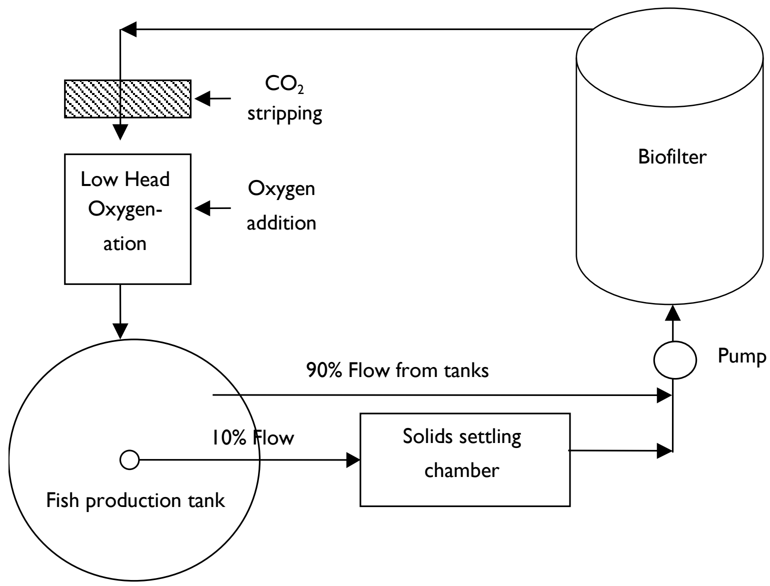
RAS has several important considerations that influence potential success. Location is important as there must be adequate farmable water available to the site; good water quality during all stages of production is critical. Management is challenging as several environmental parameters need to be managed 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 influences 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, CO_2, alkalinity and suspended solids. A generalized unit process diagram for addressing these water quality parameters is shown in Figure 9 on the next page.

[8] This section was developed with the assistance of our SME, Dr Michael Timmons, a specialist in recirculating systems.

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.

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 are less able to use available oxygen. The high carbon dioxide level of the water affects the fish's 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 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, 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 health and survival if these parameters are allowed to exceed normal values. If not corrected, the fish 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 fish.

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 is critical to maintaining good quality conditions to ensure that fish health is maintained.

RAS has some important positive features.

- Indoor RAS offer the advantage of raising fish in a controlled environment, permitting measured 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 a fish'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 every week, week in and week out, they have a competitive advantage over outdoor tank and pond 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 (infected). Conversely, in a 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 has been aimed primarily at higher price, niche markets. These may be the live or on-ice product 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, and labor costs are very similar. In fact, feed costs may be less than in other systems, as it is easier to match feed to nutritional needs. 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[9], 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;
- 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.

[9] Simmons, personal communication

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 inefficient because of poor management.

RAS-produced animals provide a very small percentage of the aquaculture output produced 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). RAS is used to produce a majority of the tilapia produced in the USA (~ 20 million lb/year) since the demand for live tilapia will support a farm price of roughly $2.50/lb whole basis.

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 gram 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 CO2 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 yellow perch (there are some yellow perch growers in the Midwest; one is a multi-million dollar company with plans for expansion[10]). Hybrid striped bass use of RAS is declining as the costs are higher. One major RAS (Kent Sea Tech (California)) was shut down in 2009 and converted to algae production. Australis is producing Barramundi in Massachussets for upscale food service and retail. AquaGreen (Perkinston, MS) is producing stocking fingerlings of pompano and there are many operations producing ornamental fish (where RAS has been successfully applied).

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

10 This plant purchases private mortality insurance.

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.

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 culture 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.

3.5 Biosecurity

For commercial success, an aquaculture operation must maintain aquaculture animals at densities far greater than normally found in nature. The animals must survive and grow rapidly. Regardless of the culture system used, the fish producer must maintain an environment that supports good fish 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 disinfected easily or thoroughly, 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 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 a lot or stock of fish 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.

- When purchasing eggs and fish, the number of different suppliers should be kept to a minimum to reduce the risk of pathogen introduction. Each supplier should be visited to determine whether the farm practices satisfactory biosecurity. If not, then fish should not be purchased from that source.

- **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 fish 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. This isolation is imposed to prevent the spread of contagious disease to other fish 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, fish 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, have normal skin color and no lesions on the skin or fins. Fish should be feeding and behaving normally within 24 hours after arrival. 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 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 fish to ongoing quarantine resets the clock to zero.

- One objective of quarantine is to increase the probability that, if the fish 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 fish 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 pathogens, e.g., Ich, 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 are shown in Table 3. We include in this table both freshwater and saltwater species to illustrate the relatively small number of vaccines available for all aquaculture.

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 V1	Infectious Salmon Anemia, furunculosis, vibriosis, cold-water vibriosis	Salmon and trout
Flavobacterium Columnare Vaccine, Avirulent Live Culture	AQUAVAC-COL	Columnaris (caused by *Flavobacterium columnare)*	Catfish
Edwardsiella Ictaluri Vaccine, Avirulent Live Culture	AQUAVAC-ESC	ESC (caused by *Edwardsiella ictaluri*)	Catfish
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

Source: US Fish and Wildlife, Approved Vaccines for use in aquaculture

- 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 vaccinations or transport. 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 including, 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.

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[11], 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.[12]

The named perils in the trout policy included some trout diseases[13] 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.

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.

---

[11] 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.

[12] 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.

[13] 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 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.

- 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.[14] 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, 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.

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

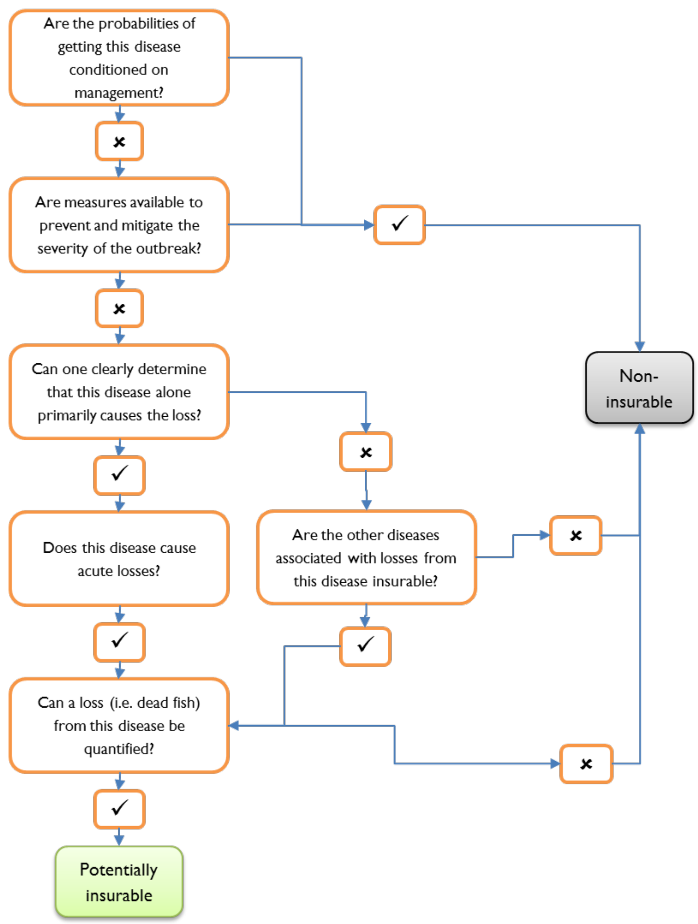
[14] Despite the experience of FSA in administering the NAP program.

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.

Figure 10: Decision tree for identification of insurable 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. 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 alongside (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 fish 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).

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. A recent large-scale survey of catfish production practices revealed that more than one-half of operations lost food-size fish to predation (and 5% of these cases resulted in losses of more than 2,000 pounds per event). However, despite the seriousness of the threat, there are management actions that can control this peril and its inclusion as a named cause of loss in an RMA insurance plan would be subject to adverse selection.

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 is protected from many of the weather effects, while ponds, raceways, 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. In particular, large-scale raceway facilities require a substantial volume. Drought and excessive demand on limited resources can threaten the maintenance of conditions for productive aquaculture. While, this peril can be reduced by the initial location decision for the enterprise, the threat from this peril is largely determined by natural factors such as rainfall or drought.

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. Some evidence of the frequency of consultation with veterinary specialists is found in the recent catfish study.[15] Here, 32% consulted specialists to identify a specific disease, despite a strong recommendation that treatment with drugs should not be undertaken unless the farmer is confident that the disease or parasite has been adequately identified.

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.[16] Hatchery crop insurance would differ significantly from insurance for freshwater fish produced in the main grow-out systems. The hatchery sector is diverse, demanding different protocols for each species. Also,

---

[15] Draft report, Catfish 2010, Health and production practices for food size catfish in the United States, 2009, APHIS/National Animal Health Monitoring System.

[16] The 2005 Census of Aquaculture identified the following numbers of hatcheries producing broodstock or eggs: hybrid striped bass – 1 (eggs); catfish – 39 (broodstock); tilapia – 3 (broodstock); trout – 24 (eggs); largemouth bass – 5 (broodstock); and freshwater prawns – 1 (broodstock).

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 demands close attention to detail. The number of eggs that hatch and their survivability as newly hatched fry varies considerably among species. 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 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 as the products are in the hatchery for a very short period, and they are extremely vulnerable to mortality. In addition, it is difficult to assess a fair market value for either the eggs or the fingerlings that are sold as there are no published representative prices for the products of other species hatcheries.

Additionally, some freshwater 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 many other federally and state funded hatcheries, most of which are supporting wild populations of trout, salmon, largemouth bass, and other native species. For example, Pennsylvania State funds 15 trout hatcheries to supply recreational uses and population enhancement projects.

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.

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 trout or catfish stocked, mortalities, sales and purchases of trout/catfish 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 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 methods. 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 ensuring 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. All of the species under review except catfish and tilapia are carnivorous and can cannibalize.

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 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.

4.3.3 Inventory measurement

Counting live fish

Accurate counting of fish 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, fish are harvested when they are quite small (0.5 – 1.5lbs). Therefore, in order to produce substantial tonnage, tens of thousands and sometimes millions of fish must be stocked in an on-growing system. It is understood that 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.

Second, the live fish must be handled 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 fish going into the system, albeit subject to the errors described. Almost all juvenile farm fish 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.

Before being netted or pumped into the transport container, fish 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 fish 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.

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. 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

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.[17]

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 rot and disintegrate quickly, or they may be cannibalized by the other fish, 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

[17] 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 in marine or lake net pens are re-counted **if there is significant evidence that an escape may have occurred**.

outlet screens, float or sink to be collected by divers in the case of net pens. 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 raceway or unit.

No one has found a passive, mechanized way yet to determine total biomass in a fish 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. 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.
- 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 fish 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[18]. 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)[19]. The previous feasibility study

[18] 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 because of food falling to lake or marine floors.

[19] 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.

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.

Using growth rate formulae

Most commercial aquaculture facilities need to estimate inventory for production planning purposes and to estimate feed requirements. As indicated above, one common formula used is the specific growth rate (SGR) that is based on the natural logarithm of body weight:

SGR = ln FBW (final body weight) – ln IBW(initial body weight) /D (number of days)

However, experience has shown that the SGR has limited value as it does not account for important environmental factors, such as water temperature differences. As growth rates vary at different sizes of fish, the SGR may not be accurate over long periods of time. It is also limited in making comparisons between different groups of fish.

An alternative formula for fish growth prediction is the thermal-unit growth coefficient (TGC), which is based on the exponent 1/3 power of body weight and also takes water temperature into consideration.

TGC = (WF x 0.333) – (WI 1/3) / Σ [(T)(days)] x 100;
where WF and WI are final and initial weights in grams, T is water temperature in °C, and days represents the number of days between initial and final weight.

Once TGC is determined, the final body weight is predicted over a specific period using the following:
[WI x 0.333 + Σ (TGC/100 x T x D]3

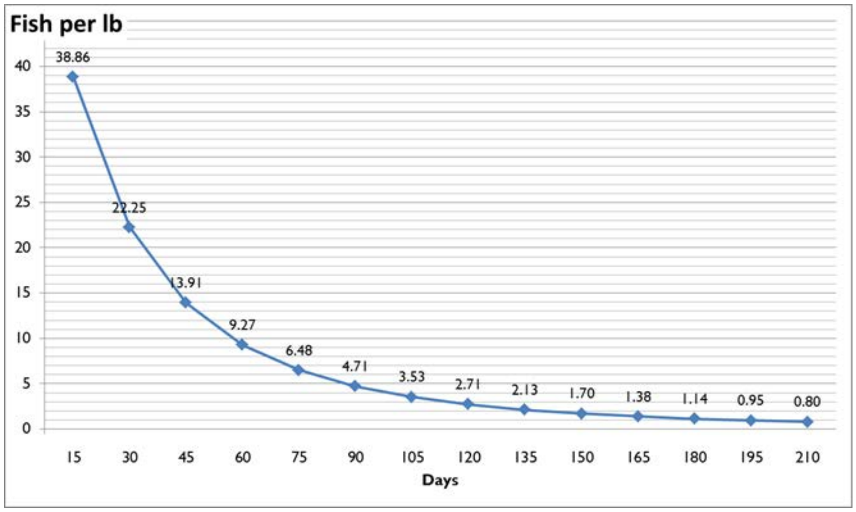
The following example used production records from a large commercial trout farm in Idaho. The beginning weight was 36.4 grams and the ending weight was 445.5 g, water temperature was 14.8 °C, and the growth interval was 140 days:

TGC = (445.5) x 0.333 – (36.4) x 0.333 ÷ (14.8 x 140) x 100 = 0.2087

To predict growth, if we begin with fish at 5.88 gram each or 77.16 fish/pound and grow them for 180 days. What will be the predicted final weight?
Final weight = [5.88 x 0.333 + (0.2087/100) x 14.8 x 180]3 = 399.5 grams or 1.14 fish/#.

This can easily be converted to fish/pound and plotted on a graph, such as the one in Figure 11.

Figure 11: Prediction of fish per lb over production period



Source: Dr. Gary Fornshell, personal communication

Using the TGC allows some comparison among facilities operating at different temperatures, when other factors are the same. However, TGC is sensitive to strain, nutrition, and other factors and consequently has most accurate application when it is applied to the production of a specific hatchery whose products are subject to standard growing conditions and feeding regimes.

Inventory accuracy

The inventory on a fish or crustaceans 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 fish and those that have died and been recovered and counted (where that is possible); and
- less an unknown number of fish that may have died and not been recovered, or may have escaped, been cannibalized or predated.

And unless the fish 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 fish 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 ponds, and consequently this factor alone works against our support of an insurance plan for all species grown in ponds. For trout grown in raceways, 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 TGC system identified above is likely to be appropriate for these companies, although even here we doubt that it is appropriate for an RMA plan given its sensitivity to different strains, feeding regimes and the impact of comingling of different batches. Certainly, given the wide range of trout production systems, we doubt that there is sufficient confidence to apply the TGC system for all trout production for food.

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 period. Such data are not available for any aquaculture system or species. Cross-sectional survey data were collected in 2004 as part of the NRMFPA. We have only been provided the summary of this data and the resulting rating plan from the NRMFPA. These data are unlikely to represent the current situation in the aquaculture sector. Hence, 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.
- 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. There is little evidence that the aquaculture sector is anxiously seeking out crop insurance.

4.3.5 Data availability

Production history

A survey of catfish and trout growers was conducted by NASS for the NRMFPA study. This was a farm-level survey performed during 2005 for catfish, trout and baitfish. The survey was conducted in the major producing states. The first section of the survey provided general information on the operation including acreage and production, details on production ponds, geographical location, and risk characteristics, including systems, water sources, liability, financial and stocking details. The second section provided production losses over the last ten years. Other information gauged interest in an insurance product based on coverage levels and premium rates. A summary of this data was provided to us in the study through the NRMFPA reports. A discussion of how this data was used to compute loss costs is included in the Rating and Pricing section of this report (Section 4.3.6).

A detailed description of current production practices is only available for catfish. The USDA released to Promar a draft study in June 2011 on catfish production practices.[20] This study included a detailed survey on production practices and health issues of catfish farming. It included a section which summarized the mortality losses on catfish operations.

The study grouped growers into various surface area size groups (1-19, 20-49, 50-149 and over 150 acres) and two regions (East and West). The West region included all farms in Louisiana, Arkansas, and the Mississippi Delta region (flat land) and the East comprised farms in the hilly region of Mississippi and Alabama.

The first statement of the 'major mortality loss' section said "Discerning mortality and tracking losses along with the causes in catfish ponds is difficult, especially in large ponds that are harvested and understocked[21] for many years."[22] Regardless, the results of the producers' responses to questions on losses were tabulated. The definition of a 'major mortality event' was 5 percent or more of inventory lost over a period of up to 2 weeks in 2009. The percentage of operations with a major mortality event in 2009 was reported to be 12.2%.

The next section included details on causes of food-size-fish loss. The survey asked about any loss and also about the size of loss in groupings (None, Light, Moderate, or Severe). Diseases were split into various types of disease. For any cause of loss, predation was the highest with 53.9% of all respondents. Two diseases were the next most common, Enteric Septicemia of Catfish (ESC) and Columnaris with 36.6% and 39.0% respectively. Low dissolved oxygen was next with 28.1%. In total, 79.2% of producers experienced any loss according to the survey.

The size of losses was defined as 'average loss per event (lb)'. The following sizes of loss were used:

---

20 Draft report, Catfish 2010, Health and production practices for food size catfish in the United States, 2009, APHIS/National Animal Health Monitoring System.

21 Understocked means that other species share the pond with catfish.

22 Draft report, Catfish 2010, Health and production practices for food size catfish in the United States, 2009, APHIS/National Animal Health Monitoring System, page 85.

- Light (less than 200 lbs)
- Moderate (200 to 2,000 lbs)
- Severe (more than 2,000 lbs)

The data was also split by 'operations' and 'ponds'. Unfortunately, the data wasn't split into size of operation. The average number of fish per acre was over 7,000 and size of fish at harvest is about 1.25 lbs according to the study. If we assume an average weight for a fish is 0.5 lbs then each acre would hold 3,500 lbs. of fish. A 'severe' loss of 2,000 pounds would be less than 5% for a farm with 20 acres. If any insurance product were to be designed than the percentage of losses would be a critical component of the actuarial rating methodology. The percentage of loss should be defined in the same unit as the insurance. Therefore, the survey lacked some of the critical data needed to build a rating structure. Also, one year of data would not be credible by itself for a frequency/severity of loss database to build a rating structure.

The causes of loss with events that were the most severe were listed as 'Other' (53.2%) followed by anemia and trematodes (26.1% and 26.6% respectively). Low dissolved oxygen had severe losses 22.8% of the time, while the other causes of losses had much less severe losses per event. Predation, which had the highest frequency of loss, had 67.2% 'light', 27.7% 'moderate' and 5.1% 'severe' loss events. This was somewhat consistent with the NRMFPA study that mentioned that low dissolved oxygen was a major concern to the catfish producers since severe losses were caused by it.

While the survey does have useful information, it does not contain enough data to build a credible actuarial rating model for two primary reasons:

- Only one year was used in the survey; and
- The frequency and severity of losses by perils were not linked to size of operation; this is inconsistent with an insurance product (e.g. a 2,000 lb. loss for a small farmer may cause an indemnity, but would not be significant to a large producer).

Price data

In general, the only price data available offer those aquaculture products that are sold into commodity markets. There are data for catfish, salmon, shrimp, and imported trout. The other species are sold mainly into niche markets as described in the species profiles. There is no regular information collected or reported publicly on any of these other fish or crustacean markets. Appendix I 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.

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 ways of addressing them.

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 fish 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 harvest 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 many of the markets serviced with the exception of catfish and 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. [23] 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 substantial 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. A major limitation for aquaculture growers is only 35% of liability is allowed to 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. The states of Arkansas, Louisiana, and Mississippi are not eligible for AGR-Lite plans (or AGR). Alabama is eligible for AGR-Lite. 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.

Since AGR-Lite is available in several counties that were recommended as pilot counties in the NRMFPA study we priced two example farms in counties where AGR-Lite is available to determine what guarantee and premium a hypothetical grower would have had available under this program. In Greene County, Alabama, we selected "Fish/Aquaculture" as the commodity. The unsubsidized rate for a 75% coverage level and 90% payment rate was 0.176. The AGR-Lite unsubsidized rate for "Trout" commodity in Twin Falls, Idaho was 0.129. If additional commodities are added a diversification factor is used to discount the premium for AGR-Lite, but this was not contemplated in this example. These rates are significantly higher than the rating plan that the NRMFPA was proposing, although AGR-Lite would cover more perils. Since there is no participation in AGR-Lite we could conclude that the aquaculture industry is unaware that it exists, or it is too expensive for the perceived coverage, or agents do not aggressively market AGR-Lite. Because there has been no participation in AGR-Lite, we are unable to conclude that the rates are anywhere close to accurate for this program.

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. Also, this would not cover the actual loss of livestock

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

(aquatic species). 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: [24]

- 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 survey of catfish and trout farmers to establish the rates. The NASS survey asked growers to provide a "loss range" percent for each loss and the amount of loss within the range. Table 5 shows the amounts for trout:

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

Table 5: Loss rate and percent of loss, NRMPFA

Loss Range (Percent)	Percent of Loss
0 to 5	2.5%
5 to 15	7.5%
15 to 30	22%
30 to 50	37%
50 to 100	65%

The proposed policy from NRMPFA had only one coverage level set at 85%. Using a statistical model (Tobit) the variables of significance were expected production and the region of production (East/West). Without going into all the details, the premium rate was calculated as a function of expected production and region. A Western grower with 500,000 lbs. of expected production would have a rate of approximately 0.035.

The catfish rating was similar except more variables of significance were found including expected production per acre, state (Arkansas had a higher load), horsepower of generators per acre for aeration and back-up generators (yes/no). The Tobit model was also used to calculate the premium rates. A catfish grower in Mississippi with 4,000 lbs. per acre, a back-up generator and an aeration HP/acre of 3.0 would have a rate of approximately 0.010.

Two of the expert reviews analyzed the actuarial rating aspect of the NRMFPA. Don Armstrong's review stated:

"My recommendation is to approve the program in spite of the weak actuarial presentation."

Armstrong noted several computation errors and questioned using such a sophisticated model (Tobit) when the data provided was very weak. Armstrong also developed an alternative rating model using a methodology similar to the APH method of continuous rating. This would use the expected production rather than the reference yield as a ballast to the continuous rating formula.

The expert review performed by David Bickerstaff recommended disapproval based on computational errors and counterintuitive rating. These included the fact that the 15% deductible was not being calculated in the loss cost for the trout. Also, the rating table for trout needed to be adjusted so marginal rates were charged, otherwise growers with more expected production would pay less in total than growers with less overall production. Bickerstaff was critical about the surcharge for Arkansas since the location and exposure to perils were similar to growers across the river. Bickerstaff also noted that there was a positive coefficient for the horsepower of aeration per acre. He felt this was counterintuitive to tell a grower that they needed to pay more premium if they had higher horsepower per acre. The NRMFPA report noted this as well but said it was a proxy for intensity (fish per acre - the higher biomass per acre, the greater the risk).

All of the comments made by the actuarial reviewers 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%.[25] 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.

The catfish and trout data from the NRMFPA were the only data that was available for this feasibility study. Much data measured the number of fish sold and number of farms per year for each species. While these data are useful to understand the overall riskiness for all growers in a state, it is not relevant to the determination of insurance rates.

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 aquaculture. We do note that if a plan would go forward a rating plan could be built but it would use a lot of assumptions and/or require fixing some of the issues from the prior NRMFPA report.

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. In general, we suspect that generally compressed margins in the industry are likely to serve as a serious constraint on interest in mortality insurance. Also, we note that there has not been an intensive effort to seek out crop insurance by any of the participants in the industry. When the proposals for catfish and trout plans were rejected by the FCIC Board there appears to have been little industry reaction through their associations. Few in the industry were aware of the initiative in the last Farm Bill that resulted in this study. The major stimulus for insurance 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 NRMFPA. 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

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

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[26], 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, no wholesale agencies are known to be active in this market at this time. Given the secrecy 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

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

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[27]. 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,

[27] 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).

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.

- **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).[28] 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.[29]

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 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.

---

28 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."
29 FSA informed us that these data were not available for analysis.

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, honeybee 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, honeybee 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 any 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

National Oceanic and Atmospheric Administration (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 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 United States and outline key considerations in relation to insurance covering mortality. The detail provided varies for each species. While catfish and trout were well covered in the previous study, a recent review of catfish production practices has provided new information of relevance to insurance. One of the authors of the NRMFPA trout profile has reviewed that study and confirmed that there are no significant changes in production practices since that was written. For the most part, with the exception of catfish, there is relatively little description available of the range of the current production practices for the species under review. To fill in the gaps, we have relied on our SMEs and from interviews with sector experts. We had specific species assistance for catfish from Dr Carole Engle, for trout from Dr Gary Fornshell, and for tilapia from Dr Mike Timmons. In general, the crop insurance issues facing the production of finfish in ponds are similar for all species.

5.1 Hybrid striped bass (*Morone saxatilis* X *Morone chrysops*)

Status and trends

The striped bass and the white bass were crossed for the first time in the mid-1960s to create the hybrid striped bass. Originally, it was raised to restock lakes and reservoirs as a sport fish. Hybrids began to be raised as a food fish in aquaculture by the mid-1980s following development work at a research institute in North Carolina. Little is known about global production as it is not identified in FAO production statistics.

The industry has been under considerable pressure as competition from imported seafood and other US-produced live and on-ice fish has resulted in consistently low prices, while production costs have gradually increased. As a result, the industry has moved to cheaper pond-based production systems that involve lower levels of investment and operational costs.

The outlook continues to be tough as annual production costs are expected to increase 3% and prices by only 1%. Producers around the country consistently rank the price of feed as their largest concern as the very high fishmeal and plant protein prices have exerted considerable pressure on the sector. Other leading concerns include regulations and access to fingerlings. As with all aquaculture, hybrid striped bass face considerable challenges from the US federal, state, and sometimes county rules influencing production and marketing.

One of the owners of the large tank-based company that recently ceased operation of hybrid striped bass in 2009 is reported as saying:

> *"a number of operational expenses eventually made staying afloat farming fish impossible. Feed costs doubled, airfreight for fresh fish to the East Coast tripled and seafood imports flooded the market; energy and water costs soared. All the while fish prices remained level."*

Competition from imports has been an important factor. There is no clear information on the level of imports of this species and volumes quoted are anecdotal. Imports are all frozen fillets and do not directly compete with live or fresh, on-ice product. However, these imports (mainly from Taiwan) do add extra pressure in a market where consumer knowledge is very low and where product labeling fraud is widespread (some fish species are regularly mislabeled facilitating the substitution of some higher value species with cheaper ones.) Market sizes for fish can range from 1 to 2 pounds depending on customer requirements. Recent months have seen very healthy prices and renewed optimism within the industry.

Output (volume and value)

The development of the industry has been documented by data collected by the Striped Bass Growers Association (SBGA). This association has regularly assembled data on the sector through the University of North Carolina (Sea Grant North Carolina). This data extends back to 1986 and is based on a survey of major producers plus input from state and regional aquaculture specialists.

From 1986 to 1990 the production grew from almost nothing to almost 2 million pounds. By 2000, production had grown to 11 million pounds, which ranked hybrid striped bass as the fifth largest species in US aquaculture production, and fourth overall in value. Since that date, output has fluctuated, falling in the early 2000s to rise to its peak in 2005 and 2006 at 12 million pounds. In 2009, 8.5 million pounds production was reported and a similar volume in 2010. Total production has decreased since then because of financial pressures.

The estimated output is just over 8 million pounds at an estimated value of $29 million for food production, plus another $3 million for fry and fingerlings. The value of output has changed little during the last decade, primarily because of falling price levels.

Number of producers

The annual Striped Bass Growers Association survey indicates that there are now between 60 to 70 farms growing hybrid striped bass. Of these, there are roughly 25 operating at a commercial scale and selling over 100,000 lbs per annum. The 2005 Census of Aquaculture recorded 67 farms producing food-size fish, another 17 farms producing stockers and 9 farms producing fingerlings and fry.

Concentration of ownership

In 2000, there were about 70 producers, although more than 60% of the output was reported to be in the hands of just three companies. Today the concentration of ownership is likely to be slightly less than this; industry observers suggest there are four larger sized operations producing more than half of the output.

Regional distribution of production

There is a modest concentration of production in North Carolina and Texas. In 2005, the Census of Aquaculture recorded 24 growers representing just under 50% of production in these two states. However, there are small numbers of producers in many other states. As the optimum water temperatures for rapid growth are quite high, there's focus of production in southern states. In northern states, production can only take place in recirculating tanks which maintain water temperatures. The SPGA survey does not describe production by state.

Markets

Roughly 80 percent (6.5 million pounds) of the 2010 output of 8 million pounds is sold fresh ('head on/on ice') through wholesale channels into major local and regional markets. Roughly 2 million pounds were sold live into large metro markets serving largely Asian American (and some Hispanic) consumers. These large metro markets include New York, Boston, Los Angeles, and Toronto. This proportion has remained relatively constant over the last seven years, although it expanded slightly in 2010. The live market is targeted by several species producers and is a relatively small and highly competitive niche market. There is evidence that the market is saturated, although it still offers a premium over chilled on-ice sales at the farm gate. Most of those producers servicing live markets are based in the East and Northeast.

Price data

There is no data regularly published on the average prices or price ranges recorded in key markets. There are no recorded prices of live fish moving into large metropolitan markets. The average ex farm price recorded in the SBGA annual survey was $4.6 per pound for live and $3.75 per pound for chilled. These are historically high prices.

Availability of production history and other data

Apart from a regular annual report on the state of the industry undertaken by the SBGA, there are no data available on production history. This report reviews changes in production, production methods, sales, reported prices, reported production costs, reported production plans, domestic fry and fingerling production and imports, global trends, and industry challenges.

The Census of Aquaculture in 2005 was the last official assessment of the levels of production and the structure of the industry. However, because of the relatively small numbers of producers in each of the states, there is very little descriptive data available on industry structure. Since that date, estimates of production are made and published in the National Marine Fisheries Service publication 'Fisheries of the United States'. The latest published data refer to 2007. The same data are reported to FAO and published in their FishStat Aquaculture production and value database (last data available for 2008). Official estimates rely primarily upon the SBGA annual survey.

Occasional academic studies report on production systems and economics, although papers on economics are for the early 2000s and are not representative of current pond culture costs.

Biology

Hybrid striped bass result from crossing striped bass (*Morone saxatilis*) and white bass (*Morone chrysops*). This cross is more amenable to aquaculture and grows more quickly than either parent species. The move to the hybrid striped bass in the United States was initiated because of restrictions placed on the commercial harvest of wild striped bass. Hybrid striped bass can live in water with various levels of salinity, although most commercial production is undertaken in freshwater. They are able to withstand more variation in water temperature and survive with lower levels of dissolved oxygen.

Until recently, the industry has relied on wild fish for broodstock, although a concerted effort to develop a national domestication program has been underway for several years. Commercial hatcheries breed female white bass with male striped bass. Female white bass are easier to acquire and spawn than their striped bass counterparts. This cross is called a sunshine bass. If the female is a striped bass and the male is a white bass then the offspring is called a palmetto bass. The offspring are sexually viable and can reproduce. There are now five hatcheries producing fry and fingerlings for the rest of the industry; one hatchery in Arkansas is reported to supply a large share of the fingerlings required by the industry. Breeders have focused on improving the rate of growth and disease resistance. The culture of hybrid striped bass is still at a relatively early stage and there are significant research needs covering a wide range of issues from breeding to feed development.

Hybrid striped bass are carnivorous fish and need to be taught to eat feed pellets during the early production stage. By three weeks, fry are able to survive exclusively on finely ground high-protein feeds.

Other challenges are similar to those in other pond production systems; appropriate water quality must be maintained and crowding and other practices that cause stress must be avoided. Hybrid striped bass may be able to survive for short periods when conditions deteriorate, but there may be some adverse reactions. Immediate action to correct adverse conditions is necessary. The water temperature is critical and this needs to be constantly monitored. Ideal temperatures are between 77 and 80°F. Dissolved oxygen levels of 5 mg/L are important, although lower levels can be tolerated for short period. A pH level of between 7 and 8.5 is required, although it can go as low as 2.5 for a short period while growth rate is reduced when it goes as high as 9.0. Un-ionized ammonia should be less than 0.5 ppm as should nitrite-nitrogen. Also, when daily total ammonia nitrogen increases to 1.8ppm the fish will not grow as efficiently. Fish began to die when TAN was 2.5 ppm.

Seasonal spawning is a constraint as this confines production to a seasonal pattern. Fingerlings are available during the spring and early summer. There have been efforts to overcome this problem, although these have not been adopted commercially.

Hybrid striped bass dislikes handling and consequently is challenging to farm in RAS. Also, it is slightly less tolerant of poor water conditions than catfish and tilapia.

Production system

In the 1980s when hybrid striped bass aquaculture began, 98% of the production took place in tanks in RAS. However, by 1990 and 2000 tank production dropped to 77% and 40 % of total production respectively. Today, tank production is estimated at just 5% of total production. Production has shifted to ponds as tank production involves higher investment and costs. Ponds also involve less stress for the fish.

The ponds vary considerably in size, and range from 1 acre to more than 500 acres. The larger ponds pose considerable challenges in terms of inventory assessment. As with all pond-based systems, there is a continuous challenge maintaining appropriate water quality.

The first stage of production involves the growing of fry to fingerling size (roughly 1 to 3 grams) over a period of 1 to 2 months. During this stage, fry are stocked at 150,000 to 200,000 per acre, with an expected survival rate of 20%. Historically, two additional stages were involved in the production process. A second stage involved stocking fingerlings weighing about 1 gram at 10,000 to 15,000 per acre and raising them to juvenile fish (125 - 225 grams). At this stage, there was an expected survival rates of 80 to 85%. As a third stage, the fish are transferred to a final grow-out pond (or section of a pond) with a stocking rate of about 3,500 to 4,000 fish per acre. Here they are raised to final weights of between 1.5 to 2.5 pounds.

Some larger operations have adopted a two-phase system, with fingerlings being grown to market weight (referred to as the direct stock system). There is considerable debate on the merits of the two system, Some producers retain the three stage system as the advantages of exploiting the full carrying capacity of ponds outweigh the disadvantage of increased handling and movement of stock.

The direct stock system skips the second phase and thereby reduces the labor and feed costs. Labor costs are reduced because there is no harvesting, size grading or restocking between phases two and three. Also, there is some fish mortality every time the fish are handled. Those supporting the direct stock system suggest that it reduces the time from the first stocking to harvest from 29 to 21 months. It is estimated that the 20% decrease in the growing time leads to a 30% reduction in the production costs. Survival rates in the direct stock system are estimated to be 90 to 95% under good management.

In direct stock method the grow-out phase begins with stocking graded fish that weight 3g, which is larger than the old three phase system. They are stocked in ponds with densities of 3,750 to 4,000 per acre between June and September. They have also been taught to eat formulated diets. Uniform sizes and ample pelleted food will reduce instances of cannibalism and reduce the number of undersized fish at harvest.

In larger ponds (more than five acres) a system is needed to make the fish congregate. Aerators will achieve this goal. In smaller ponds, a stationary floating ring can be set up with food in it. This will prevent the feed from being carried by the wind and will attract the fish to the ring. Producers need to monitor their fish to make sure that all of the fish are eating. Fish that are not eating need to be separated from the group so feed can be broadcast, which should encourage them to eat. Once they are eating they can be returned to the group.

Hybrid striped bass are carnivores and hence great care must be taken in providing enough feed to constrain cannibalism. Also, ponds should be stocked with fish of similar size to prevent larger fish cannibalizing smaller fish.

A producer may supply markets at a range of market weights. Partial harvests may be undertaken to supply the live market. Seining a pond is used to extract product of the desired market size. All fish going to the live market need to be purged in an unstocked purging pond before delivery to market.

The three most important costs of production are feed, energy and fingerlings, in that order. There are no recent data on the costs of production although feed is now likely to be a much more important cost component. Feeding rates and formulas are dependent on the age and size of the fish. The dietary needs of hybrid striped bass changes as they mature.

Length of production cycle

The grow-out phase extends for 15 to 18 months and the entire production cycle is 18 to 24 months. Fingerlings are entered into grow-out ponds between June and September and the harvest takes place between October and May in the following year.

Key factors affecting success

Key factors include efficient training to consume feed, good pond hygiene, appropriate water quality and temperature, low levels of stress on fish, and appropriate feed. Feed quality is important. As hybrid striped bass are carnivorous, it has been challenging to reduce the fishmeal proportion of the feed. However, feed composition today includes a wide range of alternative proteins.

Perils

In general, hybrid striped bass are relatively disease-resistant. However, there are several important parasites and diseases, most of which are influenced by the quality of management (e.g., parasites and pathogenic fungal, bacterial or viral infections). The most important tend to be the bacterial diseases resulting from infection by *mycobacterium* spp. and *streptococcus iniae* and various parasites. Both of these bacterial infections can be transmitted to people. The former disease (*mycobacteriosis*) is a chronic and debilitating disease that is untreatable. Prolonged use of antibiotics has not been successful and is prohibitively expensive. The only response is to destroy the infected stocks and disinfect the entire facility, including all equipment that has been in contact with the fish, before restocking.

Most bacterial pathogens are ubiquitous in fish and water and only cause morbidity and mortality when fish are stressed or suffer some injury. Other bacterial diseases include *Flavobacterium columnaris*, a disease found in many freshwater aquaculture species, and *Edwardsiella tarda*, although the latter is less common in hybrid striped bass. Viruses are not considered a serious problem, although they have been reported occasionally. *Saprolegniosis* is the main fungal disease considered to be economically important, although it tends to be opportunistic and is associated with bacterial parasitic infections.

Each of the above are best prevented by good management practices such as ensuring good water quality, appropriate stocking rates, and good nutrition and avoiding stress. For example, salt or formalin can combat parasites and fungus, chelated copper compounds can be used to deal with algae, potassium permanganate can be used to modify water quality, and various FDA approved antibiotics can be used in the feed to treat bacterial diseases.

Good management practices are imperative for maintaining disease-free aquaculture production facilities and ensuring an appropriate environment for the fish. It is important to limit diseases brought into facilities by applying basic biosecurity precautions. For example, purchasing disease-free certified fish from the hatchery, excluding all wildlife, sterilizing equipment, and controlling personnel and transport movement. Water entering tanks and ponds also needs to be pretreated and tested before use in production ponds. Pond fallowing (say every 3 to 5 years) and sterilization can also help reduce vulnerability to disease.

In addition, there are perils associated with the malfunction of equipment providing aeration or pumps or other engineering involved in ensuring appropriate quality of water. There are risks associated with predators, theft, and malicious damage. In addition, there can be catastrophic losses from natural weather events such as floods and storms and from other natural events such as earthquake. There are no data on the incidence of these perils on the hybrid striped bass industry.

Classification of perils

With the exception of the catastrophic perils, hybrid striped bass producers have the potential to avoid or minimize the impact of potential perils through good management practice. Management procedures that either modify water quality or apply fish health products to treat diseases and parasites are available. Only one disease of commercial importance is untreatable.

Crop insurance issues:

- 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. As with any aquaculture production in ponds, there is a major challenge identifying fish inventory at any point in time. There are likely to be high levels of inaccuracy in inventory estimates.
- 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 on measurement).
- In three stage systems, there is movement of stock between different containment structures. This makes inventory assessment even more challenging.
- Partial harvests of live fish for the live market may frustrate inventory or loss calculations in direct stock or three phase systems.
- There may be difficulty identifying the specific cause of loss for mortality resulting from some diseases or parasites without specialist veterinary inspection. Producers must be willing to invest in inspection to confirm that any cause of loss is a result of an insured disease peril. This could influence willingness to invest in insurance.
- Most perils are closely associated with the quality of management. Management affects the design and servicing of the facilities, the quality of the water, the treatment of diseases or parasites, and biosecurity. Thus, there is danger of moral hazard and adverse selection.
- There is a lack of a wide range of data required for actuarial assessment. For example, there is no clear data describing the structure of the industry, basic production data, the use of production practices, the incidence of disease or other perils, the normal level of mortalities, or prices when sold at different periods of the year. There are also no data describing individual production variability. This lack of data inevitably results in risk of adverse selection and the identification of rates that are likely to be much higher than the industry can pay.

5.2 Largemouth bass (*Micropterus salmoides*)

Status and trends

The largemouth bass is a native species and popular as a game fish. The native range of largemouth bass extends from the lower Great Lakes, to the Gulf Coast, Florida and north on the Atlantic coast to Virginia. It is primarily raised throughout the United States for recreational fishing and for enhancement of wild populations in rivers and lakes. However, it is also grown for sale on a very small scale as a live fish destined for the Asian live fish markets in major metropolitan areas. It is illegal in some states to rear or sell largemouth bass for stocking and in others sale for food is prohibited (e.g. Florida).

Output (volume and value)

There is no current information on the size of the sector, nor of the trends in production. The 2005 Census of Aquaculture reported 4.1 million pounds of food-size fish were produced with a value of $8.3 million. The reported total value was $10.6 million which included $1.7 million as the value of output of fry and fingerlings. The 2005 Census results suggested that roughly 10% of production is destined for food production.

Number of producers

The 2005 Census of Aquaculture identified 58 farms in the United States producing food-size largemouth bass, 52 producing stockers, and 97 producing fingerlings and fry (NB some farms may be producing each of these categories). In addition, there were 94 producers raising largemouth bass for nonfood purposes (either for recreational fishing, or for waterway population enhancement).

Concentration of ownership

The sector is characterized by relatively small aquaculture enterprises, with very little concentration of ownership.

Regional distribution of production

The results of the 2005 Census of Aquaculture indicate that largemouth bass is produced in many different states with relatively little regional concentration. It is produced in a wide range of environments with Alabama, Arkansas, and Ohio each producing 10% of the total recorded production in 2005.

Markets

Largemouth bass are grown primarily as a game fish and only a very small proportion of the sales are destined for human consumption. Fingerlings and yearlings are sold for stocking into lakes for non-commercial sport fishing. Larger bass are also used to stock fee fishing recreational ponds. Food sales service the highly competitive market for live finfish in Asian markets in large metropolitan areas. Few are sold for food on ice. In northern locations, largemouth bass spawn later in the year than in southern areas. This means that they are entered into grow-out ponds during summer months and are not available for harvest until the end of the second year/beginning of the third year of grow-out (say October to June). Consequently, there is a shortage of live fish of the species available from cooler locations during the summer months. It is understood that there is no sale of largemouth bass for processing (e.g. for filleting or other preparations for market).

Price data

There is no data regularly published on the average prices or price ranges recorded in the recreational game fish market. There are no recorded prices of live or on-ice fish moving into large metropolitan markets.

Availability of production history and other data

No data provide a representative description of the industry. The industry largely comprises relatively small largemouth bass operations and there is no regular collection of data on production, the type of production system, scale of operation, yields, expected mortalities, incidence of disease, or production costs and revenues. Occasional academic studies report on production systems and economics, although most of these are dated. It is very difficult to gauge the true extent of differences among industry participants.

Biology

There are two recognized subspecies of largemouth bass: the northern largemouth bass (*Micropterus salmoides salmoides)* and the southern Florida largemouth bass (*Micropterus salmoides floridanus)*. The subspecies and their hybrids can be distinguished only by genetic testing. The Florida subspecies rarely survive in climates that are more northerly where ice covers shallow ponds. The largemouth bass is prized for recreational fishing because of its fighting qualities. They are voracious predators that can eat other fish from a fairly early age. Cannibalism is a major challenge in commercial aquaculture, especially at the fingerling stage.

Spawning is influenced by water temperature and hence there is a marked seasonality in production, even in more southerly locations.

The growth rate depends on food supply and environmental conditions. The females are larger than the males and the Florida largemouth can grow to almost twice the size of the northern strain.

Production system

Fingerlings need to be trained to accept feed before they can be moved to grow-out ponds. To do this the fish are removed from natural sources of food, crowded, and presented with highly palatable prepared food (usually fish-based) at frequent and regular intervals. Some may never accept artificial feed diets. Fingerlings may need to be graded to prevent the larger fingerlings cannibalizing the smaller ones. Fingerlings are vulnerable to losses that can reach 20% of the original stock. Growth rates are strongly influenced by water temperature.

Largemouth bass are raised in ponds, similar to catfish production. Relatively little is known about commercial aquaculture production of largemouth bass for food markets. Production methods developed several decades ago to produce small fish to restock ponds, lakes, and reservoirs remain common today.

The introduction of more modern, technologically advanced methods of commercial aquaculture of largemouth bass for food is still in process. There is relatively little agreement on stocking rates or ideal feed for food production. Few of the fish used in aquaculture have been genetically selected or improved for food production.

Largemouth bass tolerance of dissolved oxygen levels and ammonia appear to be similar to catfish. However, they appear to be very tolerant of high nitrite concentrations. Nutritional research is very limited, although it is recognized that this carnivorous fish requires high-protein diets.

Length of production cycle

The ideal market size of food-size largemouth bass sold in urban immigrant markets is 1.5-2.0 pounds. It can take three years to achieve this size, although there is a lack of research on the factors that can improve growth rates and reduce the period of production to a suitable size for food markets.

Key factors affecting success

As in much of aquaculture, feed costs are by far the largest operating cost component for most aquaculture products. These normally exceed 50% of operating costs, but are likely to be higher for predatory species such as largemouth bass. Relatively little is known about the ideal least-cost feed required for efficient largemouth bass production.

Perils

There are several diseases, most of which are influenced by the quality of water quality management (e.g., pathogenic fungal or bacterial infections). *Cytophagus columnaris* can be an important problem during fingerling production, although treatment with antibiotics such as terramycin, or the use of other treatments such as a salt bath or potassium permanganate can overcome the problem. Most disease issues are those associated with other pond production systems. There appeared to be no diseases that are specific to largemouth bass until the appearance of largemouth bass virus (LMBV) in wild populations in 1995. It has since been identified in 17 states. Little appears to be known about this virus in terms of its pathogenesis, epidemiology, and natural history. There is no information on its impact on aquaculture facilities, although there is anecdotal evidence that fish gain immunity.

In addition, there are perils associated with malfunction of equipment providing aeration or pumps or other engineering involved in ensuring appropriate quality of water. No data are available to describe the incidence of these perils. In addition, there are catastrophic losses from natural weather events such as floods and storms.

Classification of perils

With the exception of the catastrophic perils, largemouth bass producers have the potential to avoid or minimize the impact of possible perils through good management practice. Management procedures that either modify water quality or apply fish health products to treat diseases and parasites are available. Largemouth bass virus remains untreatable; however, in view of the lack of basic scientific understanding of this peril it is unclear whether appropriate biosecurity or management procedures can be adopted to avoid infection.

Crop insurance issues:

- Multiple inventory assessments would be required to identify a baseline from which to measure loss. As with any aquaculture production in ponds, there is a major challenge identifying fish inventory at any point in time. There are likely to be high levels of inaccuracy in inventory estimates.
- 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 on measurement).
- There may be difficulty identifying the specific cause of loss for mortality resulting from some diseases or parasites without specialist veterinary inspection.
- Most perils are closely associated with the quality of management. Management affects the design and servicing of the facilities, the quality of the water, the treatment of diseases or parasites, and biosecurity. Thus, there is danger of moral hazard, and adverse selection.
- There is a lack of a wide range of data required for actuarial assessment. For example, there is no clear data describing the structure of the industry, basic production data, the use of production practices, the incidence of disease or other perils, the normal level of mortalities, or prices when sold at different periods of the year. 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. These problems are more severe for largemouth bass than for other pond grown species, with the possible exception of freshwater prawns.
- A multiyear production cycle may lead to moral hazard issues in an annual insurance plan.

5.3 Tilapia (hybrids of *Oreochromis niloticus* and *Oreochromis aureus*)

Status and trends

Globally tilapia is one of the most successful farmed species. Currently it is second only to the various carp as a farmed food fish and global sales are estimated at $5 billion, compared with $1.7 billion 10 years ago. Tilapia culture is successful because of the development of new strains and hybrids, monosex male culture, better understanding of nutritional requirements, novel water treatment methods, and the application of these advances to a variety of semi-intensive and intensive systems. The species is relatively easy to produce in aquaculture, and it will readily hybridize in captivity. Tilapia is a very hardy fish, and can cope better with handling and water quality than most other species. Tilapia domesticates well, it has a good feed conversion ratio, it is managed relatively easily, and it is well accepted in the marketplace. Also, the species is more tolerant of higher stocking rates than many other species.

Global production has grown rapidly with major advances in China, Southeast Asia, Brazil, Egypt and Central America. China is by far the largest producer and is a major supplier of frozen tilapia to the US market. Central American suppliers aim to supply the fresh fillet market, although this is a major challenge given the competition from frozen product from China. In the US, tilapia were first introduced in the 1950s and used to control aquatic vegetation in ponds. Commercial production for food began in the 1980s. Tilapia is not native to the US and is considered a threat to native freshwater fish. They reproduce quickly, eat the eggs and juveniles of other fish species, and hence can endanger some native fish species in some areas. As a result, the majority of tilapia farms in the US use closed recirculating systems and are located where tilapia have already become established, or where cold winters kill escapees.

Output (volume and value)

From the early 1990s to 2000 output increased very slowly to roughly 20 million pounds. There has been very little growth of the sector since 2000. The vast part of production in the US is in RAS, with a low level of production in ponds in southern states. The most recent estimates state that the US produces 20 million pounds or 9 million metric tons of tilapia annually. This is an estimate provided by an industry expert to NASS. The 2005 Census of Aquaculture reported 17 million pounds was produced for food with a value of $29.5 million. The Census reported a total value of $31 million which included $1.6 million as the value of output of fry and fingerlings.

Number of producers

The 2005 Census of Aquaculture identified 172 farms in the United States producing tilapia. One hundred twenty eight of these were producing fish of food-size and 16 producing stockers and 28 fingerlings and fry. Apart from this, there is no information on the current number of farms; although experts we have contacted have indicated that 'commercial' production is likely to be in the hands of no more than 30 to 40 farmers. The US Tilapia Growers Association has no data.

Concentration of ownership

There is little information on size distribution of farms, although one farm is reported to be producing roughly 20 to 25% of the total production and three farms (including the lead farm) have a reported capacity for between roughly 30 and 40%. An APHIS report on emerging diseases indicated that in 2005 about a dozen farms accounted for more than 90% of total US production. The rest of the sector is characterized by small aquaculture undertakings.

Regional distribution of production

The various tilapia species are the subject of prohibition from aquaculture in some states as they are considered exotic and invasive species. The risk of escaped fish to wild stocks is low where there is no access to natural waters such as in well-designed recirculating systems. The risk is moderate in enclosed ponds and tanks and high in nets, cages, raceways, and unenclosed ponds and tanks. Despite this, tilapia production is widespread throughout the United States. The 2005 census identified 31 states with production facilities with California, Hawaii, Alabama, Florida, and North Carolina having more than 10 producers. However, because of confidentiality constraints, output is only quoted for five of these states and value of output for four states.

Markets

In the US, tilapia is the fifth ranking species in terms of consumption (estimated to be 1.21lbs dressed weight per capita in 2008). It has been identified in market research surveys as the second most popular fish species, with only salmon being more popular. Tilapia consumption in the US has grown from about 135 million pound tons in 2002 to roughly 500 million pounds in 2010. However, the US tilapia industry cannot compete with imported frozen fillets from China or fresh and frozen fillets from Central America. The volume of Chinese imports has increased every year for the last five years and now represents the vast bulk of US imports (56% in 2005 growing each year to 75% in 2010). Ecuador is an important supplier of the US market (with frozen product and it, Costa Rica and Honduras are the leading fresh fillet suppliers.

Most of the US industry is focused on supplying niche markets, primarily live markets servicing immigrant populations in large metropolitan areas. These markets are protected from foreign competition, but, by definition, niche markets are limited in size and market expansion is challenging.

Supplying live fish in good condition represents a significant challenge. During transport, unless appropriately treated, water conditions can deteriorate quickly and can result in mortality. There is a very small proportion of the US industry supplying the fresh market, although this is understood to be based on the use of correctional facility staff in Colorado for processing.

Price data

There are no regularly published price series for live tilapia. The value of supplies entering the US market in whole, frozen or fresh form is available, and because of the volume involved, these set the tone of the market. However, most US product is sold into the live market and data on the prices of species in these markets are not available. There have been various attempts to assemble data in large Asian-dominated live fish metropolitan markets. However, these attempts have not been successful, largely because of the unwillingness of market traders to cooperate. It is likely that significant price differences exist between different urban markets because live transport of fish is expensive and can be limited by local and state regulations. Thus, arbitrage between different markets is limited. Also, while most tilapia sold into the live market are harvested at approximately 1.5 pounds, there is variation by region with some markets accepting smaller fish and others larger. Prices of frozen imported tilapia (mainly Chinese) are quoted in Fulton's Fish Market Weekly Price (See Appendix 1: Sources of aquaculture fish prices).

Availability of production history and other data

There are no data describing the sector's production, scale of operation, yields, anticipated mortalities, incidence of disease, or production costs and revenues. As with some other species in aquaculture, there are some occasional academic studies reporting on production systems and economics, although none of these provides representative data.

Biology

Tilapia is a warm water fish species that is native to Africa and the Middle East. Tilapia is both farmed and captured (in lakes), however its recent success is through more intensive aquaculture. Tilapia is tolerant to saltwater conditions, although saltwater production is not widely practiced in the United States and is not common elsewhere. In US aquaculture, the most important species are the Nile tilapia (*Oreochromis niloticus*) and the blue tilapia (*Oreochromis aureus*) and their hybrids. The Mozambique tilapia has been used in several hybrids. Many different hybrids are in production with Nile tilapia genetics being most prominent. The different species and hybrids vary in terms of survivability and growth rate. For example, the blue tilapia grows slowly but is one of the most cold tolerant species of tilapia while the Nile tilapia grows faster in warm conditions. A wide range of hybrid strains are available to tilapia growers and, within any given region, these hybrids are likely to perform similarly.

Male and female tilapias grow at different rates. The larger males grow almost twice as fast and out-compete the females for feed. There are several methods for producing all-male tilapia fingerling batches. The most common in the US is to spawn female tilapia with males that have two Y chromosomes or use a synthetic hormone in feed fed to fry to initiate sex reversal. The former method is patented and buyers pay a license fee. The latter method requires a special permit from the federal government. The hormone 17a-Methyltestosterone (17MT) is under an Investigational New Animal Drug exemption and is subject to investigations of tilapia, human and environmental impacts as part of efforts to gain FDA-approval. Hormone treatment is common in many countries as it is a relatively simple process. This procedure is possible as tilapia is not sexually differentiated for several days after the eggs have hatched. If female tilapia receives a male sex hormone in their feed for 3 to 4 weeks, they will develop as phenotypic males. The procedure is generally accepted as safe and is widely used internationally, including on tilapia imported into the US.

None of these methods guarantees 100% males in any batch. However, most keep females to a very low proportion of the total population. Commercial tilapia growers purchase all male fingerlings (or breed their own) and use monosex culture.

In their natural habitat, they occur in a wide range of freshwater locations as they can cope with wide temperature ranges (from 46 to 108°F). In general, in culture the water temperatures need to be above 60°F to avoid stress and related problems. The species is mainly diurnal and is omnivorous. In their natural environment, they feed on a wide range of plants and animals from phytoplankton and algae to insects and other finfish and crustaceans. They spawn year round in their natural environment if they are in warm water (above 68°F). As noted earlier, they are more tolerant of intensive culture systems than many other species.

Production system

Fingerlings from improved strains are widely available, and there is a sound understanding of the essentials of good tilapia husbandry. Tilapia readily accept compound feed and one major advantage in aquaculture is the ease with which tilapia aquafeeds can be produced using non-marine origin proteins (plant and alternative animal-based products – although this means that the nutritional benefit of high levels of Omega-3 fatty acids is missing).

- Reproduction: There have been many advances in selective breeding and genetic improvement with excellent breeding programs existing in a wide range of countries and YY males are available globally. Substantial strides have been made in improving genetic lines and the use of hybrids.

- Breeding: Tilapia are asynchronous breeders. Spawning occurs year-round. Male and female broodfish are placed in tanks with controlled environments. The female tilapia collects the fertilized eggs in her mouth and incubates them for 3 to 5 days. Fry gather at the edge of a tank or pond and can be collected with fine-mesh nets. Fry collection can begin 10 to 15 days after stocking.
- The fry stage: Fry remain close to their mothers for 10 to 14 days before they swim freely. When they are separated from their mothers, hormone treatment may be used to induce sex-reversal. Fry are transferred to the nursery ponds at about 30 days.
- The nursery (fingerling) stage: After sex-reversal, fingerlings are generally nursed to an advanced size before they are stocked into grow-out facilities. A nursery stage is required to improve survival. Here it is very difficult to generalize as there is considerable variation in practices. It is common to move fingerlings to the grow-out stage at 2 to 4 grams although some transfer at much larger sizes (e.g. 30 to 40 grams). The movement to grow-out tanks may be dictated by the availability of capacity. If capacity is short, then fingerlings may be held back.
- The grow-out phase: Grow-out can be undertaken in a wide range of different systems depending on the availability of key inputs and market opportunities. Indeed, it is clear that there are many variations in production practice even under one main type of production system. In general, in intensive RAS, cohorts stay together and there is no intermingling of stock of different sizes. This avoids the potential of disease transfer and is more efficient in terms of management of feeding.

Tilapia can be grown in ponds, net cages in lakes, raceways or various forms of intensive tank culture. The production system selected is mainly dependent on the climate. Lake production involving floating cages is not practiced in the United States. Pond culture of tilapia is similar to that undertaken for catfish, with the only exception being the necessity to drain and harvest tilapia ponds in the fall before onset of lethal cooler water temperatures. Pond culture is a cheaper method of production than recirculating systems, although there is less control over key environmental conditions. Also, outdoor production is limited as productivity decreases if the temperature of water falls below 68°F. It is estimated that 90% of US tilapia production takes place in RAS tanks, and most of these tanks are indoors (APHIS suggested that only 60% were enclosed in the mid-2000s – it is thought to be higher today).

Intensive tank culture has been categorized into three separate subcategories: combined intensive-extensive (CIE) systems (where earthen ponds serve as biofilters before water is recirculated into concrete grow-out ponds); closed-cycle, geothermal culture systems (minor importance – a feature in Idaho); and, intensive RAS using advanced water treatment methods. The latter represent the bulk of US tilapia production. There are a small number of integrated systems, where the wastewater is closely linked to the production of crops. RAS tank culture facilitates higher levels of intensity and greater control over the management of the production system. Feeding and harvesting is also less labor intensive. However, while it is possible to generalize about the principles of RAS, the design of systems in the US varies greatly from operation to operation.

Producing tilapia in recirculating systems in tanks is much more expensive, primarily because of the capital costs. However, in temperate regions they do have the advantage of year-round production under controlled conditions that facilitate sound management practices. Recirculating systems must be designed to facilitate appropriate levels of feed, adequately removing solids, and maintaining appropriate oxygen levels throughout the growing period.

Recirculation is critical to successful tilapia production. The recirculation process must ensure that waste is removed and replacement water is of a consistently high quality. The percentage replacement of water each day varies depending on the system, but there should be no buildup of organic matter so that fish health and rapid growth are maintained. Maintaining water quality is essential and tilapia operations need to monitor and control basic conditions such as temperature and levels of dissolved oxygen, pH, ammonia, nitrite, alkalinity, chloride, and calcium. There are generally agreed parameters for each of these.

- Temperature — Optimum growth is achieved at 80 to 84°F (27 to 29°C), but acceptable growth rates are reported at 77 to 90°F (25 to 32°C). Temperatures in the extreme upper range make it more difficult to maintain dissolved oxygen concentration.
- Dissolved oxygen (DO) — Operating levels of 5.0 to 7.5 milligrams per liter (mg/L) are recommended. Growth and feed conversion are affected by DO concentrations below 3.5 mg/L. Recovery is possible from short-term exposure (less than 10 minutes) to low DO concentrations, although this will depend on stocking densities.
- pH — Tilapia can survive a wide range of pH, from 5 to 10, but are said to grow best at pH 6 to 9. A minimum pH of 6.8 is suggested as the lower limit of tolerance for the nitrifying bacteria of the biofilter. Due to the presence of dissolved carbon dioxide, high pH is generally not a problem in tank systems.
- Ammonia (NH_3) — Ammonia exists in two forms in the tank environment, un-ionized NH_3 (highly toxic) and ionized NH_4^+(less toxic). Concentrations of un-ionized ammonia greater than 1.0 mg/L can cause stress. The relationship between pH and the toxicity of Total Ammonia Nitrogen (TAN), un-ionized ammonia and ionized ammonia can be critical.
- Nitrite (NO_2^-) and Chloride (Cl^-) — Concentrations greater than 5 mg/L of nitrite-nitrogen can cause stress if chloride (Cl^-) is low (less than 10 mg/L). Rock salt or calcium chloride can be used to alleviate nitrite toxicity.
- Nitrate (NO_3^-) — Nitrate toxicity can occur if levels in water re-use systems exceed the 300 to 400 mg/L nitrate-nitrogen range. Normal water exchanges during filter backwashing or solids removal generally control nitrate concentrations.
- Carbon dioxide (CO_2) — Carbon dioxide levels in excess of 40 mg/L cause lethargic behavior and interfere with feeding. Dissolved carbon dioxide gas stripping is required to keep pH above 6.8 and avoid damage to biofilters.
- Calcium hardness — Levels between 50 and 100 mg/L. of dissolved calcium relieve stress in fish (calcium chloride can be added and also increases chloride (Cl^-) levels).

- Alkalinity — This should be maintained between 100 to 250 mg/L by adding a soluble carbonate or bicarbonate source. Dissolved carbon dioxide reduces pH, so supplemental alkalinity may be required if CO2 stripping is poor.

Identifying the precise water quality parameters required for tilapia culture has been challenging although there are recommendations for each of these. It has been noted that:

> *"Water quality variables interact in complex and often poorly understood ways. Variables such as water temperature, pH, hardness, general fish health, feeding history, and sound and light stressors all have a role in determining whether the lethal level of a particular parameter has been reached." Source: De Long et al, Tank Culture of Tilapia, Southern Regional Aquaculture Center, SRAC publication #282, Revision June 2009.*

Feed is the major operating cost, and hence the most useful performance indicators relate to feed use. Feed input and other management factors that promote production are captured by the ratio of the production to maximum carrying capacity (P/C). For tilapia, P/C ratios of >4.5 are possible and ratios of >3 may be necessary for profitability. However, intensive practices are required to reach these very high P/C ratio levels. This can pose a major problem for crop insurance as high P/C ratios are usually achieved by multiple cohort culture with regular partial harvests and restocking (and challenges measuring inventory and assessing losses). As noted earlier, in general, multiple cohorts are avoided, although partial harvest may be unavoidable to meet the demands of the market.

Before harvest, tilapia needs to be purged to avoid the development of off flavor and to help maintain the quality of water during transport. This involves withholding feed, ensuring adequate water exchange and reducing water temperature before harvesting and transport. Non-iodized salt added to the hauling tank can reduce stress and facilitate transport for up to 18 hours with little mortality. Partial harvest represents a challenge for purging – usually once a partial harvest is purged, so is the rest of the batch in anticipation of further purchases.

Length of production cycle

In general, in RAS, the production cycle can last from 7 to 12 months depending on the market conditions. It is difficult to define the length of each stage as growers adopt different practices. Product can be harvested throughout the year in large RAS. Production and harvest in ponds may be limited by weather conditions.

Key factors affecting success

Tilapia are resilient fish, however water quality is still critical. As noted earlier, RAS require attention to detail. Feed costs are by far the largest operating cost component for most aquaculture products, and tilapia is no exception. The recent very high feed costs have placed pressure on producers to pay close attention to tilapia nutrition.

Perils

Above all, a successful tilapia RAS must have effective control systems as intensive methods increase the risk of catastrophic loss due to equipment or management failures.

- Consequently, the managers of these intensive production facilities need accurate, real-time information on systems status and performance, in order to maximize their production potential. At production densities approaching and even exceeding 120 kg/m3 (1 lb/gal), failure of a circulation pump or aeration system can result in severe stress to the fish and probable catastrophic 100% losses within minutes. Expensive and sophisticated monitoring and control systems and components from other industries, such as the wastewater and petroleum industries, have been successfully modified for use in aquaculture. However, only a small fraction of their processing power is usually employed. Today, with the rapid decrease in costs of computers, software, and off-the-shelf monitoring hardware, systems of this type are within the reach of even small producers and are mandatory for large-scale production facilities.
- Given the value of the standing fish crop, the potential losses to the business are large. Consequently, minimally, automatic and continuous monitoring of the most important water quality parameters, e.g., oxygen, and water levels, is critical. The attentive human operator is a valuable monitoring and alarm system. However, most facilities are not staffed 24 hours a day and humans cannot monitor key water quality parameters.

The following represent a short list of potential emergencies in intensive recirculating systems.

Type / System	Causes
Beyond your control	Floods, tornadoes & hurricanes, wind, snow, ice, storms
Organizational preparedness required	Electrical outages, malicious damage, theft
Staff errors	Operator errors, overlooked maintenance causing failure of back-up systems or systems components, alarms deactivated.
Tank water level	Drain valve left open, standpipe fallen or removed, leak in system, broken drain line, overflowing tank.
Water flow	Valve shut or opened too far, pump failure, loss of suction head, intake screen plugged, pipe plugged, return pipe ruptures/breaks/glue failure
Water quality	Low dissolved oxygen, high CO_2, supersaturated water supply, high or low temperature, high ammonia, nitrite, or nitrate, low alkalinity.
Filters	Channeling/clogged filters, excessive head loss
Aeration system	Blower motor overheating because of excessive back-pressure, drive belt loose or broken, diffusers plugged or disconnected, leaks in supply lines.

The following illustrate the life support priorities in intensive recirculating systems:

- **High** (fast response time – minutes)
  - electrical power; water level in tank; dissolved oxygen - aeration system/ oxygen system

- **Medium** (moderate response time – hours)
  - Temperature; carbon dioxide; pH
- **Low** (normally slowly changing – days)
  - Alkalinity; ammonia-nitrogen; nitrite-nitrogen; nitrate-nitrogen

At high stocking densities (greater than 40 kg/m3, 1/3 lb/gal), dissolved oxygen requires the most rapid response time. If either water flow or aeration is interrupted for any number of reasons, low oxygen and the resulting stress can result in mortality within minutes; chronic or even short periods of a few hours of low oxygen can lead to disease problems. At low stocking densities (less than 40 kg/m3, 1/3 lb/gal), basic parameters to be monitored include system electrical power, tank water level (high and low), aeration system pressure, and water flow through the filters and tank. All of these parameters can be monitored by simple digital sensors.

There are several diseases, most of which are influenced by the quality of management. The most serious and clinically significant pathogens affecting tilapia in RAS are bacterial diseases. Viruses and protozoan parasites are rarely a concern. Fungal diseases are only significant if the tilapia are under constant stress and in ponds.

Tilapia is reported to be vulnerable to iridio virus, although little is known about this pathogen and it has not been identified in indoor cultured tilapia and is extremely rare in any form of culture in the US.

Protozoan parasites are only a concern in outdoor systems. In most commercial production, all fingerlings are kept in quarantine and treated to eliminate any parasites. This simple biosecurity procedure has eliminated parasites as a cause of concern.

The leading bacterial diseases are Streptococcus, with the most threatening strain being *Streptococcus iniae*, although other strains (e.g. *Streptococcus agalactiae*) have been implicated. The fish are most vulnerable in the grow-out phase (say from 100g to 1 kg), although it can impact smaller fish. Another bacterial disease, columnaris *(Flavobacterium columnare)*, can be a serious problem for tilapia producers. It is highly contagious, particularly for fry and young fingerlings, although it can affect tilapia in the grow-out phase. Tilapia can survive columnaris, although the rate of mortality is usually high. *Aeromonad septicemia* is caused by the bacteria *Aeromonas hydrophila* and this can be a problem although it is less common than the other two bacterial diseases. Each of these bacterial diseases results from stress from poor water quality, crowding, poor nutrition, or fluctuations in water conditions. Thus, careful management is critical (e.g. avoiding crowding and very high stocking densities, ensuring appropriate oxygen availability, reducing the water temperature, reducing feed). Bacterial infections can be treated with antibiotics delivered in feed, although great care must be taken in identifying the precise disease and the appropriate antibiotic.

A series of recent reports have implicated bacteria from the family *Francisellaceae* as the cause of disease in farmed and wild fish and shellfish species[30]. Tilapia is one of these species, (along with hybrid striped bass, salmon, and several other species). It is possibly underreported. *Franciscella* is a new and virulent disease

[30] J Fish Dis. 2011 Mar;34(3):173-87, Francisella infections in fish and shellfish, Birkbeck TH, Feist SW, Verner-Jeffreys DW. University of London Marine Biological Station, Millport, Isle of Cumbrae, Scotland, UK.

that has not been reported in the US. Mortalities can be high and, as the disease may be transferred via live fish movements, it poses a significant threat to tilapia operations. No treatment is available and an outbreak would involve depopulation and disinfection of the facilities. Comprehensive biosecurity systems are essential to avoid infection.

Classification of perils

As with other aquaculture species, there is a large number of perils that affect performance that can be influenced by management. Only one disease has no treatment, although that can be prevented through severe quarantine proce*dures as part of a disciplined biosecurity plan. None of these diseases are insurable because they are* prevented by sound management practices.

We conclude that only naturally occurring events are insurable.

Crop insurance issues:

- The industry is comprised of a relatively small number of commercial growers with one very large unit (representing roughly 25% of the total output). Also, there is substantial diversity in RAS design. Identifying risk pools is challenging and this could result in adverse selection.
- Large capital-intensive RAS tilapia operations will have private insurance available to them and some may have purchased this insurance where lenders or equity partners have demanded it.
- Diversity of production practices within the same system makes it difficult to confirm inventory and then to measure losses.
- While the most professional commercial growers are likely to retain separate cohorts of tilapia, some may move fish between tanks to increase carrying capacity and improve overall efficiency. This raises the possibility of moral hazard.
- Partial harvests may make it difficult to assess losses at the end of the production stage and could be a moral hazard risk.
- Identifying inventory will require calculations involving detailed records of entrants, mortality, feed used, and movements, plus the use of assumptions about feed conversion and growth rates. These measurements are challenging and could be subject to error.
- There may be difficulty measuring losses because of the challenge of measuring inventory.
- The design and configuration of the system and its engineering are factors that might increase risk of diseases.
- With the exception of catastrophic natural perils, most perils are closely associated with the quality of management of a facility. These perils are uninsurable.
- There is no data on live tilapia prices. This seriously constrains the development of a mortality insurance plan.

5.4 Catfish (*Ictalurus punctatus* & hybrids)

As part of the catfish assessment, Professor Carole Engle reviewed the previous NRMFPA catfish profile for critical changes in practices. This profile summary relies heavily on the National Animal Health Monitoring System (NAHMS - part of APHIS) report on catfish health and production management practices conducted in 2010. This report updates its 2003 review of catfish production practices. The report provides interesting and recently observed insights that have considerable relevance to a study of crop insurance in aquaculture. We have had access to a draft of this report prior to its publication. This report highlights results from a survey of catfish producers in the four most important catfish production states (Mississippi, Alabama, Arkansas, and Louisiana), with detailed information on population estimates, stocking practices, pond characteristics and management, water quality and treatment, health issues and harvesting practices. The farms covered in the survey account for 91.5% of the total national catfish sales in 2009 and 91.3% of the water surface acres to be used for catfish production from January 1 through June 30, 2010. This report provides considerably more data than is available for any other species under review.

Status and trends

The production of catfish represents the most economically important finfish aquaculture sector in the United States. This native fish, indigenous to Southeast US, species was introduced to other parts of the Southern US as a game fish in the mid-1900s. Its commercial production began in 1970 and became the base of an important production and processing industry in southern states. In general the sector is under considerable pressure from competition from similar species from Southeast and East Asia. Prospects for growth are poor as the Southeast Asian industry becomes more professional and efficient. Antidumping measures have had no significant impact on the relative competitiveness of US production.

Output (volume and value)

Between 1970 and 1990 output grew rapidly to just over 350 million pounds. Then it expanded slowly to almost 650 million pounds in 2005. The semi-annual Catfish Production publication from NASS indicated that by 2010 output had contracted to 479 million pounds, worth $375 million. This contraction reflects the extent of competition in commodity catfish fillet markets.

Number of producers

According to the 2011 NASS Catfish Production report there were 909 catfish operations in 2011, down from 994 in 2010. The decline in catfish farms has been steady over the past decades as the ownership of production has consolidated and the sector contracted in response to intense competitive pressure from imports. According to the 2005 Census of Aquaculture, there were 1,160 farms down from 1,370 farms in the 1998 Census of Aquaculture.

There are state and private hatcheries. Many of the fee-fishing operations have their own hatcheries, to stock their ponds. According to the 2005 Census of Aquaculture, there were 1,017 farms that produced stockers, 102 farms that produced fingerlings and fry and 184 farms that produced broodstock in 2005. This information is not included in the annual NASS Catfish Production reports, so no new information is available.

Concentration of ownership

The catfish industry comprises mainly relatively small- and medium-sized operations with no significant share of output held by very large producers.

Regional distribution of production

Catfish are warm water fish that grow best in a temperature of 85°F. Consequently, production is limited to the south and southeastern regions of the United States. In 2010, Mississippi, Alabama, Arkansas and Texas accounted for 94% of the United States total of catfish production. The remainder of the production is in California, Louisiana, and North Carolina. Almost all fingerlings are produced in Mississippi.

The recent NAHMS/APHIS study (2011) of production practices in the four leading states revealed significant differences between the scale of production in the east of the region (the rolling hills of Alabama and eastern Mississippi) and the west (Arkansas, Louisiana, and the Mississippi Delta). Farms located in the east are more than three times larger than those in the west.

Markets

Catfish are almost exclusively (95% in 2009) sold for processing into fillets. Most commercial producers specialize in selling to this market. Direct sales to consumers or local retailers are a niche market that is largely serviced by smaller producers. Today, catfish are processed into a wide range of added value products as well as sold as fillets.

Price data

The only weekly price data for catfish comes from Urner Barry. The Urner Barry Seafood Price Current publishes data on domestic catfish from the south. Prices are available for whole dressed, boneless/skinless fillets, and Value-added products, both fresh and frozen (See Appendix 1: Sources of aquaculture fish prices). Annual data is available from the NASS catfish production reports. This data is broken down by state and size of fish.

Availability of production history and other data

There is more information available on catfish production history and price data, than for any other species covered in this study. Catfish are covered in the 2005 Census of Aquaculture, like all of the other species. In addition, as the domestically produced species with the greatest economic importance, NASS has published a semi-annual report on catfish production since 1988. NASS also publishes a monthly catfish processing report. NASS produces a third report, which covers catfish feed delivery, on a monthly basis. It only includes catfish feed delivered to bona fide catfish producers and excludes catfish feed delivered to producers of other species. Mississippi State University regularly reviews catfish data and produces detailed statistical description. To this list, we can add the recent soon-to-be published NAHMS/APHIS report which provides a wide range of data on production practices.

Biology

Channel catfish (*Ictalurus punctatus*) are the predominant species in US catfish aquaculture. Channel catfish do not naturally reproduce in ponds, which gives the breeders greater control over crossing. Another advantage of channel catfish is that sexually mature fish are easily spawned, which is essential for artificial reproduction. Unlike many of the other species grown in aquaculture, fry accept manufactured feeds and growth and feed conversion efficiencies are good at all stages of production. In addition, they tolerate relatively high levels of crowding and a wide range of environments. For all of these reasons channel catfish are ideal for commercial aquaculture.

Production system

Catfish production involves several stages: reproduction; hatching and fry production; fingerling production; and grow-out. Catfish eggs are collected and hatched in indoor tanks or troughs and after roughly two weeks the fry are stocked in nursery ponds. The resulting fingerlings are transferred to earthen grow-out ponds.

Many catfish producers also produce fry and fingerlings, as well as food-size fish production. Specialized fry and fingerling producers are more common in western Mississippi and Arkansas. Almost one fifth of all operations produce all or some of their own fingerlings.

An important finding of the NAHMS/APHIS study is the significant variation in production practices among different operations. These differences highlight the challenges when considering crop insurance.

The average size of production ponds is 10.8 acres. There was considerable variation in the average pond depth. As noted earlier, the eastern farms were much larger than the ones to the west of the main production states. Also, farms in the east were primarily supplied with surface water, while those in the west were almost exclusively supplied by underground sources.

Stocking densities vary considerably with 22% of the surface area stocked at less than 4,000 fish per acre 47% at 4,000 to 6,000 fish per acre, and 30% by greater than 6,000 fish per acre.

Unspecified lines of channel catfish are raised on 82% of operations. Hybrid catfish (primarily male channel catfish crossed with female blue catfish) are grown on 21% of farms but only on 7.3% of the surface area. Roughly 13% of farms grow a number of branded lines that have been developed by universities or commercial companies. The hybrids and lines were more likely to be grown by those culturing catfish on a larger scale. Hybrids are grown in separate ponds. It appears that producers are still experimenting with hybrids.

The vast bulk of production was undertaken in continuous multi-batch production – 76% added fingerlings to ponds that were already populated with fish at various stages of growth. Single batch, 'all-in all-out' production was much more likely where hybrid catfish were being farmed (41% of farms growing hybrids). In general, single batch systems allow for more precision with management decisions, although multi-batch systems do enable exploitation of available carrying capacity.

Almost 50% of food-size fish operations stocked at least one additional fish species in addition to catfish in the catfish production ponds . The most popular were (threadfin shad, a natural food item for catfish and a phytoplankton grazer, and grass carp, a herbivore used primarily to control aquatic weeds). There were few differences in this practice between different sized farms.

The survey identified different approaches to feeding. Some fed every day to satiation (18%), others fed every day but to a maximum limit (12%), others fed on alternate days to satiation (38%), and others fed on alternate days to a maximum limit (21%).

One third of producers selected fingerlings or stockers for stocking based on price and only 20% raise specified genetic lines of channel catfish or hybrids.

Length of production cycle

It takes between 18-36 months to produce channel catfish; starting from an egg and growing all the way to a food-size fish. This time frame is regardless of whether the producer uses a multi-batch system or a single batch harvest.

Key factors affecting success

Competition from *Pangasius* species from Southeast Asia has captured market share from domestic catfish. The imports are frozen, boneless fillets and these supply a large share of total US consumption. The growth of these imports has driven down the price of domestic catfish.

Perils

The three most common perils reported by farmers in the NAHMS catfish survey are predation, low dissolved oxygen and disease. Low dissolved oxygen levels are frequently caused by other factors that are influenced by management (such as stocking intensity, feeding procedures, water quality treatment, etc.) and by natural conditions (weather, water source quality, etc.). In 2009, 54% of catfish producers lost food-size fish to predation. The larger farmers experienced significantly more predation than the smaller operations. Low dissolved oxygen was identified by 28% of operations. Again, this peril was three times more common in the largest ponds compared to the smallest ponds. The three most common diseases were columnaris (affecting 39% of operations), enteric septicemia of catfish (ESC – resulting from *eswardsiella ictaluri* infection and affecting 37% of operations) and winter kill (a fungus affecting 21% of operations).

Farmers reported that roughly 12% of ponds had major mortality events (defined as 5% or more of mortality loss over a period of two weeks) in 2009. The average losses were roughly 4,500 pounds per acre on average. Ponds with no major losses produced 1,000 pounds more than those with losses.

Producers reported 43% of ponds suffered losses from predation, 14% from ESC, 14% from columnaris, 7% from winter kill, 3% from proliferative gill disease, 1.8% from anemia, 1.7% from visceral toxicosis of catfish, 1% from trematodes and 1% from ich. 4.5% of ponds suffered from losses classified as ‘other‘ and 9.5% reported losses because of low dissolved oxygen. Each of these loss events were identified as either light, moderate or severe. The causes of loss with the greatest proportion of severe losses were trematodes (27%) anemia (26%) columnaris and proliferative gill disease (both with 11%). However, 23% reported severe losses as a result of low dissolved oxygen and 53% because of other causes of loss. More than two thirds of these 'other' losses that were severe were reported to be because of *Aeromonas* bacteria.

Management action can reduce the incidence of predator damage, although this can be expensive for large ponds and is rarely entirely effective.

To prevent disease on farms, producers have a couple of options. First, they can maintain ideal stocking densities and water conditions and second they can vaccinate or purchase vaccinated fingerlings (against columnaris and edwardsiella).

Sound management is the first line of defense. The less stress put on the fish the better. Stress and poor water quality greatly increase the risk of disease. Dissolved oxygen levels can be monitored and in many cases are. In 2009, all operations with 50 acres or more monitored the levels of dissolved oxygen in their ponds. Methods varied, but included automated sensors and hand monitors. Only roughly 50% of those with less than 20 acres regularly tested the dissolved oxygen levels. However, the lower stocking density at smaller farms reduces the risks of low levels of dissolved oxygen. If the dissolved oxygen level does drop below recommended levels then aeration can be used to increase the levels of dissolved oxygen. However, 17% of small operations had no aeration capability.

There were differences in water treatment to maintain quality. For example 30% did not use salt to modify chloride levels and 67% did not add calcium to modify alkalinity. One third of producers used no algae control treatments. Those that did, used copper sulfate, Diuron, or biological control (algae eating fish). Only 13% use any form of control of snails (a host of trematodes). Of course, this may not imply poor management as those not applying treatment may have adequate water quality.

To avoid some leading diseases, producers can stock their pond with fingerlings that were vaccinated against columnaris and ESC (using FDA approved immersion vaccines at the fry stage). In 2009, 6.2% of food-size operations stocked ESC-vaccinated fish, which accounted for 4.9% of the total catfish, and only 3.9% of operations stocked columnaris vaccinated fingerlings, which accounted for 2.7% of the catfish.

Vaccinating fish does not completely remove the risk of infection. ESC outbreaks occurred on 47% of operations that contained food-size, vaccinated fish. Even though ESC still occurs on farms with vaccinated fish, 42% of producers believed the vaccinated fish had better survival rates than non-vaccinated fish, 21% thought they faired equally and 38% didn't know. Also, 13% thought that the vaccinated fish had a better growth rate; no one reported lower growth rates in vaccinated vs. non-vaccinated fish.

The results for columnaris-vaccinated fish are similar. There were outbreaks on 59% of farms that had vaccinated fish. Outbreaks were also treated with medicated feed. Almost 50% of farmers that stocked vaccinated fish thought they had better survival rates, and 40% didn't know if it was better or worse. Over 13% thought that the growth rate in vaccinated fish was better and no one reported worse growth rates.

The number of operations stocking ESC-vaccinated fish in 2010 is expected to be 5.7% or about the same as the 2009 numbers. The number of operations stocking columnaris-vaccinated catfish is expected to grow slightly from 2.7% to 3.7%.

In addition to adjusting water quality, producers can use medicated feeds to fight bacterial infections. Only 8.2% of operations used any medicated feed as a treatment for bacterial diseases. The percentage was consistent for all operation sizes. There are three approved antibiotics: Romet, used by 50% of those using medicated feeds, Aquaflor used by 36% and Terramycin used by 26%. The larger operations used more Aquaflor.

Classification of perils

Most perils that result in losses can be influenced by management. None of the diseases are insurable because they are prevented by sound management practices. We conclude that only naturally occurring events are insurable.

Crop insurance issues:

We conclude that the picture of production practices painted by this detailed survey of the catfish industry poses very serious restrictions on the application of crop insurance to catfish.

- The NAHMS/APHIS survey underlines the substantial diversity in conditions and basic management practices undertaken by catfish farmers (e.g. scale, use of monitoring, actions to modify water quality, disease treatment etc.) This raises the threat of adverse selection as it is likely that those following less sophisticated management could benefit more from crop insurance.
- Hybrid catfish production is not yet a significant part of the industry. However, it is anticipated that it will become more popular and this suggests that separate hybrid and non-hybrid practices would need to be identified if any crop insurance product were developed.
- Multiple inventory assessments would be required to identify a baseline from which to measure loss. As with any aquaculture production in ponds, there is a major challenge identifying fish inventory at any point in time. There are likely to be high levels of inaccuracy in inventory estimates.
- Multi-batch production adds to the problems assessing inventory and losses. It requires detailed record keeping and challenges the assumptions used in assessing inventory levels such as growth and feed conversion rates.
- Mixing species within the catfish production process can also complicate the measurement of inventory, especially as some of those species are a natural food item, frustrating attempts to assess inventory using the volume of feed used.
- Despite the availability of fish health products to control two of the most serious disease perils, few in the industry are willing to invest in these products. The availability of crop

insurance for these leading disease perils could further undermine the willingness to invest in fish health products. Again, this could lead to adverse selection.

- A multiyear production cycle may lead to moral hazard issues in an annual insurance plan.
- Most perils are closely associated with the quality of management. Management affects the design and servicing of the facilities, the quality of the water, the treatment of diseases or parasites, and biosecurity. Thus, there is danger of moral hazard, and adverse selection.
- There is a wider availability of data for actuarial analysis for catfish. This may facilitate actuarial assessment, although there are other more serious challenges that lead us to conclude that an insurance plan cannot be devised that will meet FCIC standards.

5.5 Trout (*Oncorhynchus mykiss*)

As part of the trout assessment, Dr. Gary Fornshell reviewed the earlier NRMFPA trout profile and its relevance to culture today. He also reviewed inventory measurement issues.

Status and trends

Global production of trout rose from 490,000 metric tons in 2000 to 730,000 metric tons in 2009. The main producers were Chile and Norway. Chile has doubled its production since 2000, a development of saltwater production that paralleled the growth in its salmon sector. New players such as Iran are becoming important globally.

The US production of trout is considered a mature and relatively stable market that was valued at more than $63 million in 2010. The first hatcheries producing rainbow trout were located in the San Francisco Bay area in the 1870s. Trout as a food fish really took off in the 1960s. Rapid growth followed the introduction of improved and pelleted feeds. Trout farming has deep roots in Idaho, with the first trout farm being established in 1909. Idaho remains the center of US trout production.

The majority of trout aquaculture is rainbow trout; however there are a small number of farms that produce other species like the eastern brook trout (*Salvelinus fontinalis*) and the European brown trout (*Salmo trutta*). There is no clear data on how many eastern brook trout and European brown trout are produced annually.

Trout producers continue to face strong competition from low-cost imports of trout, particularly from Chile. Imports take a significant share of the market with 16 million pounds of consumer-ready trout and trout products competing with the food-size fish from US farms. This represents an estimated 40% of the consumer-ready product in the US market. This figure has grown over the last five years; Chile supplies roughly 60% of these imports from its farmed sea trout industry. While trout production in aquaculture is the third largest finfish industry in the US, FAO data indicates it accounts for less than 3% of global supplies. Another limiting factor in the US is the availability of an adequate volume of good quality water.

Output (volume and value)

The output in food-size trout grew from 51 million pounds of trout in 2003 to 67 million pounds of trout in 2007. Since then the sector has fallen to just over 45 million pounds of food-size fish in 2010. The value of production of food fish followed the same trends, peaking in 2007 at $88 million and dropping to $63 million in 2010.

Number of producers

According to the 2011 NASS Trout Production report there were 320 trout operations in 2010, down from 349 in 2009. The decline in trout farms has been steady over the past decade. According to the 2005 Census of Aquaculture there were 410 farms down from 561 farms in the 1998 Census of Aquaculture.

There are state and private hatcheries. Many of the fee-fishing operations have their own hatcheries, to stock their ponds. According to the 2005 Census of Aquaculture there were 336 farms that produced stockers, 198 farms that produced fingerlings and fry, and 24 farms that produced eggs in 2005.

Concentration of ownership

APHIS describes the US trout industry in their 2007 report titled "Assessing Infectious Disease Emergence Potential in the US Aquaculture Industry" as being made up by a few very large facilities and many small operations. The largest 20% of private farms account for more than 85% of total sales. Many of the largest private facilities are in Idaho and in 2004 made up nearly 50% of trout production by value. One company has a major share of national production and three companies represent roughly 85% of production in Idaho. The report also states that Pennsylvania had 202 facilities, North Carolina had 72 facilities and California, New York and Oregon had just over 50 facilities, but the number of owners is unclear.

Regional distribution of production

The annual NASS Trout Production publication reported that Idaho accounts for 72% of trout production and 49% of the value in 2010. Over the last decade, Idaho has consistently produced between 68-75% of the trout in the US. While the majority of trout production takes place in Idaho, many other states have production facilities. North Carolina, Pennsylvania, California, and Washington are the largest of these.

Markets

In the US, there are three main markets for farmed trout: food, conservation and restoration, and recreational fishing. Trout are marketed in three different sizes 12 inches or larger (food-size), 6 to 12 inches and 1 to 6 inches. Different markets prefer different size fish. According to the NASS Trout Production publication in 2010, 64% of food-size trout were sold to processors. After processors, sales for stocking recreational ponds, accounted for 17% of the food-size fish. Consumers purchased 6% and retail outlets purchased another 5%.

For the 6 to 12 inch fish 50% went to recreational stockers, 22% to wholesale or other producers, 11% went to government agencies and 10% went straight to consumers. The annual trout production report does not report on the percentage of 1"-6" trout sold based on their first point of sale.

The first point of sale also varies greatly depending on the state. APHIS reported that 98% of trout raised in Idaho was sold to processors. North Carolina and Washington are similar to Idaho, where 83% and 89%, respectively, are sold to processors. In California and Pennsylvania sales are mainly to recreational fishing facilities. The states with the highest percentage of direct sales to consumer are Virginia, Utah and New York.

Seventy-five percent of the food-size fish are sold to consumers. These fish are marketed in several different ways. Consumers can purchase fresh and frozen whole fish and fillets, or various value-added products. The US processing sector is concentrated with the largest producer also being a major processor and trader.

Production is very closely adjusted to market needs. A steady demand may involve bumping forward harvest, albeit at a slightly lower weight.

Price data

Annual price data is available for trout production in the annual Trout Production report published by NASS. This report is published in February and looks at the quantity and value of the trout produced in the US. This report was first published in 1988 and the most recent report covers 2010. The prices are available by the size of the fish and the state where the fish was produced. The report covers the value of trout by size and state, the amount of trout distributed and trout losses in trout intended for sale. The only weekly price reported refers to imported sea trout from Argentina and Uruguay (See AAppendix I: Sources of aquaculture fish prices). There are no price series for the other markets serviced by trout producers.

Availability of production history and other data

The most current and comprehensive data on trout production in the US comes from the annual NASS Trout Production report. Mississippi State University also publishes annual data, which gives a good idea of US trout production. The National Marine Fisheries Service produces an annual report titled, 'Fisheries of the US'. This report includes a section on aquaculture species and gives the quantity and value of trout production in the US. The latest report was published in 2009.

There are no data collected regularly on individual production history. The only data available is the trout yield verification study undertaken as part of the NRMFPA (Appendix J of the NRMFPA report). This looked in detail at practices on a relatively small number of facilities (12) in four leading trout production states in the years 2004, 2005 and early 2006. The study concluded that there was a survival rate at grow-out of 73% (including three cases of extreme loss), a feed conversion rate of 1.16, and an average yield of 78 kg per cubic meters per year. The study encountered three instances where groups of fish were unable to be tracked through to harvest (two impacted by hurricane related flooding, and one by structural failure, with losses estimated 10%, 40%, and 80% respectively). Producer mortality assessments were underestimated by producers. The mortality observed and enumerated by the producers accounted for just 59% of the actual mortality as assessed by the researchers based on a population census at stocking and at harvest.

Biology

Oncorhynchus mykiss is a salmonid species that is native to the Pacific Ocean in Asia and North America, from northern Mexico to southern Alaska. The first stocks of rainbow trout were propagated in California and the early 1900s saw offspring from Californian hatcheries being sent to many international destinations.

Trout are diadromous fish; naturally mature trout live in seawater, however they return to freshwater to spawn. An advantage of trout in aquaculture systems is that they can spawn several times a year. Unlike some of the other cultured species that can grow in less than ideal circumstances trout require clear, cool, high-quality water, making access to large quantities of this resource essential for trout producers.

Trout are naturally carnivorous predators and require high protein diets. Trout will eat almost anything; however, the biggest advances in the culture of trout were made when pellet feeds that were developed for trout became available. These diets greatly improved feed conversion ratios in farmed trout.

Production system

Trout are spring spawners in nature, but domestication, selective breeding, and the use of artificial light has resulted in a constant availability of eggs throughout the year. Most are produced from farms that stock brood fish. After hatching, fry are kept in shallow troughs and introduced to a fine particle feed. The fry are moved to nursery tanks at 2 grams until they are 100 to 120 days old and grown to 4 to 6 grams. They are then moved to larger raceways for grow-out.

There are some regional differences in stocking sizes, with Idaho stocking smaller sized trout to allow the development of immunity to infectious hematopoietic necrosis (IHN). In North Carolina, larger sizes are stocked as vaccination against enteric redmouth disease (ERM, caused by *Yersinia ruckeri*) is advisable. This involves immersion in a vaccination bath. No vaccinations are available for other diseases.

Most trout in the US are raised in flow-through systems, primarily concrete raceways, but also, on a small scale, in ponds or tanks. In flow-through systems, water is diverted from another body of water, or pumped in from another source, like a well. Gravity is the preferred method for diverting water, because pumping can be very expensive. The water coming into the trout facility must be cold and pure; trout are very sensitive to changes in water quality and to water temperature. The water coming into the system brings oxygen and the water leaving the system removes metabolic and solid waste.

Concrete raceways are lined up in parallel, so that the water flows from one rearing unit to the next. The dimension of the raceways varies considerably. The configuration of raceways can be either in parallel or in series. The water in these systems is not recirculated; rather it is aerated and re-used by the next raceway downstream. The amount of re-use depends on the topography of the site and the quality of the water. The water flowing through the system helps keep the tanks clean because waste is constantly removed; however the tanks require regular fallowing and cleaning to prevent accumulation of solids and disease risks.

The grow-out period extends from roughly 120 days from receipt of eggs to 300 days. A critical issue is the carrying capacity of the raceways. This will depend on several factors, such as water flow, tank volume, exchange rate, water temperature, dissolved oxygen content, pH, fish species and size, production targets (feeding rates), and accumulation of waste products. Trout require a minimum of 5 mg/L dissolved oxygen and a maximum of 0.0125 mg/L of un-ionized ammonia. While rainbow trout can be acclimatized to a wide range of temperatures, they are a cold-water species and an acceptable growth rate is usually achieved in temperatures of between 50 to 60°F. Using these as limits, most of the industry operates on raceways carrying between 20 and 80 kg of fish per cubic meter of water volume with water exchanges of 3 to 6 times per hour. Reuse of water of more than 4 to 6 times results in ammonia limitations, although re-use can be increased if the water is acidic. However, in the latter case other limiting factors may become important.

It will be clear from this that large volumes of good quality water are required and this represents a major constraint on trout production in the US. The concentration of production in Idaho is a result of ample supplies of good quality water from the Eastern Snake Plain Aquifer.

The carrying capacity is critical to extract maximum production. As a result, trout entered into the grow-out phase are usually size graded and moved three or four times to maintain size and uniformity, and to ensure that the fish biomass per unit of water inflow (referred to as the loading rate) remains optimal. Pragmatic management may mean mixing uniform size fish in the raceway to utilize full raceway capacity. Biomass is tracked by recording mortalities, other removals and feed input. This is critical in determining feed requirements and the need for further splitting to maintain efficient use of available capacity. Mortalities are collected and recorded daily. If they are not removed, they can block filters, prevent water flow, and spread diseases.

There is no recent published data on production costs. As noted in the patchwork of studies referred to in the NRMFPA trout profile, feed costs are by far the most important variable cost. However, there is still no comprehensive study to quantify production costs between different types of production unit or operation.

Length of production cycle

Trout are harvested for market over a three-month period extending from 8.5 to 10.5 months after hatching. Production occurs regularly throughout the year, although the rate of growth is dependent on water temperature. At 20°C the average length increase per day has been recorded at 0.75 mm, at 15°C it is 1.27 mm, and at 10°C it is 0.75 mm. Average market size is just less than one pound.

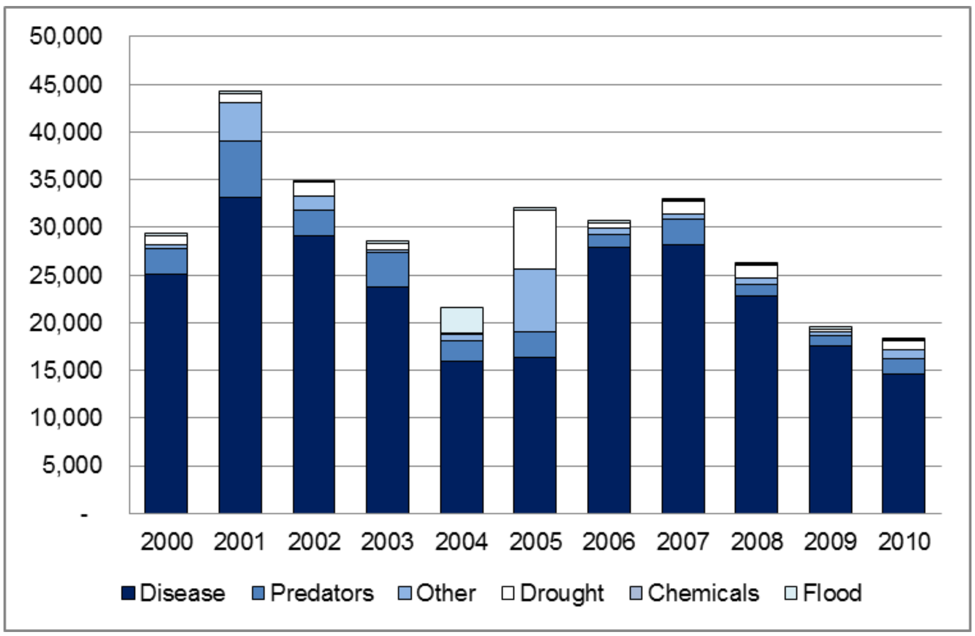
Key factors affecting success

The key issue confronting US trout production is the threat to available water supplies. Abundant water is essential for flow-through systems and may be threatened by long-term increases in demand from other uses, or by climate change or shorter-term variations in precipitation feeding watersheds and aquifers. Regulation of waste water in larger units is covered by CAAP regulations (see Section 2.2.1) and meeting these limits has represented a major issue. As with all aquaculture, attention to water quality management and biosecurity are critical management factors.

Perils

According to the 2011 NASS Trout Production report, in 2010, 18.4 million trout that were intended for sale were lost. The leading cause of loss was disease, which accounted for 79.6% of the fish, followed by predators (8.5%), drought (5.3%), chemicals (0.6%), flood (0.5%), theft (0.4%), and 'others, unspecified' (5.3%). These percentages have remained at similar levels for several years, although the number of losses varies significantly. Figure 12 below shows these losses on an annual basis. It will be seen that in recent years the number of fish lost has been falling, although this may reflect he contraction of the industry. The reported losses in 2010 represent 27% of the number of fish produced in 2010, a significant loss if all were to attain marketable size.

Figure 12: Trout losses by type, in number of fish



Source: Trout production, USDA, various years

The regional distribution of these losses reflected the concentration of production in Idaho. Idaho accounted for 70% of the fish lost, with Pennsylvania accounting for 8%, and North Carolina 6%. Almost all of the losses in Idaho arise from disease.

The NASS Trout Production report no longer analyzes the cause of loss by state. Data from 2002 show major differences in the source of loss by state. For example, the biggest cause of loss in Michigan and Pennsylvania was predators, while in Idaho this was of negligible importance. The main predators reported were birds, and they can be excluded by netting. While disease was important in Idaho, it was of little significance in Pennsylvania.

The situation with respect to disease is little changed from that reported in the NRMFPA report. The most serious disease losses in the US are associated with the two viral diseases, infectious hematopoietic necrosis (IHN) and infectious pancreatic necrosis (IPN), and the bacterial diseases, cold-water disease (*Flavobacterium psychrophilium*), enteric redmouth disease (ERM caused by *Yersinia ruckeri*), and columnaris (*Flavobacterium columnare*). Fungal diseases are not common. There is no data describing incidence of these or other diseases and parasites, or the severity of losses.

IHN is endemic in fish hatcheries and wild fish in the Pacific Northwest region of North America, and is transmitted by infected eggs, or ill fish through fish-to-fish contact, but it can also be transmitted through the water. Where IHN is endemic, good biosecurity and sanitation decreases the risk of introducing the virus to a farm. The virus is understood to be inactivated by higher water temperatures. There are still no vaccines available and an outbreak may require depopulation and disinfection. IPN poses similar challenges, with improved hygiene (disinfection of ova), certification of broodstock, and controls on fish movements representing the main methods of control.

Bacterial diseases can cause important losses. Most of these are associated with a stressful environment. A vaccine is available for enteric redmouth disease in areas that are vulnerable to this disease. Vaccines are also available for certain bacterial diseases. Also, some bacterial diseases can be treated by antibiotics in medicated feeds, although identification of the disease is important so that appropriate approved antibiotics are used.

Chemical losses remain infrequent, as do losses in commercial facilities from theft and acts of vandalism.

As noted earlier, trout production requires large volumes of water and hence, drought can be a serious challenge. Where water flow rates are reduced, there is very little that can be done to prevent damage. The impact can be minimized through aeration and oxygenating the water where water is more acidic, and modifying stocking rates and feed procedures. Drought losses vary from year to year as shown in the figure above. In 2005, there were relatively high losses because of drought.

Declining availability of good quality water threatens trout production. For example, groundwater levels in parts of the East Snake Plain Aquifer (supplying the major production area of Idaho) have declined affecting spring flows and raising concerns about current water usage rates and the demands of competing water using interests.

Classification of perils

In general, while there are several disease perils that represent serious threats to trout production, most can be controlled by either biosecurity measures (including egg, fry or fingerling acquisition) or careful management of the water and the stock. Apart from catastrophic events, trout producers have the potential to avoid or minimize the impact of potential perils through good management practice.

Reduction of water supply will directly impact production as large volumes of cool, high-quality water are essential. Drought can have serious short term effects, although this peril needs to be differentiated from the longer term impact of changes in underground water resources as a a result of climate change and increases in demand. In most cases, this latter issue is resolved institutionally by various market or non-market allocations of water extraction rights.

Crop insurance issues:

- 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. Juveniles are entered into grow-out at different ages and sizes. The splitting of age groups and occasional mixing after splitting, each raise many difficulties in measuring inventory and lead to potential moral hazard.
- The diversity of systems would create large problems identifying t-yields.
- It will be challenging to identify the cause of loss where poor husbandry has resulted in disease. Bacterial disease is uninsurable. Viral diseases, though very serious can be controlled through attention to biosecurity and appropriate sanitation procedures.
- Most perils are closely associated with the quality of management; for example, biosecurity procedures, water quality, and stock husbandry are of critical importance.
- There is a lack of data on representative prices in each of the markets served; hence it would be very difficult to identify a guarantee.
- There is a lack of data for actuarial analysis. In particular, there are few 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.

5.6 Freshwater prawn (Giant river prawn – *Machrobrachium rosenbergii*)

The textbook 'Freshwater prawns biology and farming' edited by New et al, was a key source for this assessment, as were discussions with Dr. James Tidwell of the University of Kentucky.

Status and trends

The freshwater prawn is a major aquaculture species grown primarily in Asia. It responds well to aquaculture because of its high fecundity, rapid growth, wide range of salinity and temperature tolerances and its relatively high disease resistance. The latter means that it can be cultivated inland in freshwater.

Modern aquaculture of the species began in the early 1960s as research in Malaysia uncovered ideal conditions for the production of larvae and sufficient numbers of juveniles to begin grow-out experiments in ponds. Interestingly, freshwater prawns were at the center of a major push by the US government to exploit marine resources in the mid-1960s with the setting up of the Stratton Commission. The Commission's report in 1969 was characterized as a blueprint for the nation's aquaculture development and the term 'Blue Revolution' was first used. NOAA was created and a Sea Grant program was initiated to follow the Land Grant model. One of the first projects funded under the Sea Grant program was in Hawaii and involved further development of the work on broodstock undertaken in Malaysia. This research resulted in the development of mass rearing techniques for commercial scale hatchery production of freshwater prawn PLs. As a result, production expanded in Hawaii and parts of Asia (particularly Thailand and Taiwan). From there, introductions occurred in North, Central and South America and also in Africa. The first commercial production in the contiguous 48 states of the United States began in Florida in 1970. The 1970s and 1980s saw the introduction of the United Nations development program focusing on the expansion of freshwater prawn farming in Thailand. This project generated further research and extension materials, which led to wider introduction of the crop in Asia. Today the largest production areas are China (roughly 60% of global production), Thailand, India, and Bangladesh (each with just over 10%). It is a valued crop in many Asian markets.

The US industry grew during the 1980s and 1990s because of improved hatchery and nursery procedures, better appreciation of critical farm culture practices, and improved understanding of the factors contributing to quality. However, during this period, competition from imports became intense and domestic prices were put under a great amount of pressure.

Currently, there is considerable local optimism in the US about the potential for expanding freshwater prawn production in ponds. Prawn production is well suited for small-scale farmers and markets where there is demand for locally produced, responsibly managed products.

However, the freshwater prawn industry faces a number of major challenges such as:

- the lack of local supplies of PLs or juveniles (they have poor survival when transported);
- the low survival rate in commercial grow-out operations;
- the climactic constraints that restrict production to the summer season;
- inadequate processing transport and marketing infrastructure;
- intense competition from much cheaper imported shrimp and prawns; and
- poor consumer awareness of the product and its attributes.

Output (volume and value)

Global production of freshwater prawns is viewed optimistically. In 2009, worldwide production of *M. rosenbergii* was estimated by FAO to be approximately 230,000 metric tons. While freshwater prawn production continues to grow, most agree that it will never be as large as marine shrimp production because of the challenges growing them intensively.

The 2005 Census of Aquaculture reported 20 million pounds of food-size freshwater prawns were produced in the United States with a value of $2.7 million. The total sale of freshwater prawn from all stages was valued at $3 million in 2005.

Number of producers

The most recent data on US production of freshwater prawn production comes from the 2005 Census of Aquaculture. At the time there were 80 prawn farms in the US. Of those, 76 produced food-size prawns, 1 produced broodstock, and 7 produced larvae and seed. Observers of the sector suggest that the Census of Aquaculture data significantly underestimates the number of producers. Some sources suggest that there are 250 farms in 2007, although almost all operations operate on a relatively small scale. Freshwater prawn production involves relatively low levels of investment and can be operated using fairly extensive methods. Consequently, there are relatively low barriers to entry and it represents an alternative enterprise for those farming relatively small land areas.

Concentration of ownership

The sectors comprise small-scale operations with very little concentration of ownership of overall production. In general, culturing freshwater prawn is conducive to small-scale production. Production on a larger scale has been attempted in Mississippi, but it was not successful. As noted below, it is reported that the largest farms are found in Hawaii.

Regional distribution of production

Hawaii has an almost ideal temperature range for the freshwater prawn. However, most efforts to cultivate the species have been in temperate zones such as Kentucky and South Carolina. The crop attracted attention in Mississippi among catfish growers who became disenchanted with the profitability of that species. The 2005 Census of Aquaculture indicates that freshwater prawns were produced in 17 different states with Kentucky having the most farms. However, these data provide a very poor description of the regional distribution today. A freshwater prawn expert has indicated that there are now 20 farms in Ohio, 12 in Indiana, 11 in Illinois, 18 in Kentucky, 14 in Virginia, 12 in North Carolina, 12 in Tennessee, 16 in Mississippi and 6 in Georgia. All eastern states have at least one farm. There is no data describing the distribution in western states, although production has been reported in Texas (8 farms), Arizona and California. Hawaii, the cradle of much freshwater prawn research, was reported to have had roughly 25% of US total freshwater prawn production in 2007.

Today the PLs used in freshwater prawns are produced in a commercial hatchery in Texas under RAS. Some farms produce their own PLs.

Markets

This is a niche market, and most of the product is sold at pond-side or in local farmers' markets. Some farmers organize regional festivals around the time of the prawn harvest in a bid to market a product that is poorly understood and rarely recognized. Some product is sold live into metropolitan immigrant markets, although travel times live are very limited (roughly 24 hours) and survival of travel and holding time in these markets can be risky. A small amount is processed and sold frozen, although this utilization is mainly limited to those production areas that do not have local markets. Processing must be undertaken carefully to avoid food safety problems. It is reported that some are deheaded, frozen and sold as shrimp.

The level of import competition is difficult to assess as the import data for freshwater prawns are combined with those of other similar crustaceans such as the saltwater species (*Litopenaeus vannamei, formerly Penaeus vannamei*).

Price data

There is no data regularly published on the average prices or price ranges recorded in key markets. Prices are likely to vary considerably from state to state as most are sold locally and prices depend on local availability. There is very little transparency in relation to prices sold in live metropolitan markets. For these reasons, it is extremely difficult to identify representative prices.

Availability of production history and other data

There is no data available on yields, etc. Occasional academic studies report on production systems and economics, although it is very difficult to identify average costs and revenues because production systems and prices vary considerably between different locations. In any case, there is a very poor appreciation of the prevalence of different production systems in operation currently.

Biology

Macrobrachium rosenbergii are the largest prawns in this genus, and the most commonly raised in aquaculture. It is indigenous to all of south and Southeast Asia, Northern Oceania and the Western Pacific Islands. They are naturally found in tropical freshwater that is located near brackish water, because the mature prawns live in freshwater, while larval development takes place in water with low salinity. After five days the freshwater larvae migrate to saltwater, where they undergo metamorphosis then the PLs go back to the freshwater environment. This means that when raised in aquaculture the PLs and mature prawns are kept in freshwater and the juveniles need to be kept in saltwater. This discovery opened up the opportunity for freshwater prawn aquaculture, as previously juveniles raised in freshwater did not undergo metamorphosis.

Freshwater prawns are nocturnal, omnivorous and eat algae, aquatic plants, mollusks, aquatic insects, worms and other crustaceans. They can become cannibalistic if there is no other food available, indeed they are very territorial and this means that they cannot be stocked at the same level of intensity as marine shrimp (whiteleg shrimp). The competition for resources among males means that they exhibit differential growth rates. The introduction of artificial substrates in a pond provides more surfaces and allows freshwater prawns to distribute themselves more widely in ponds and to provide cover for recently molted prawns from territorial or cannibalistic attacks. However, this is not a widespread practice in the US.

The sensitivity to low temperatures means that freshwater prawns raised in aquaculture are unlikely to survive winters throughout most of the United States, although Hawaii is immune to those winter temperatures. Death occurs at 55°F. As a result, the culture of this non-indigenous species is not seen as a threat to native species[31].

31 Indeed, US farmed freshwater prawns receive high marks from most environmental NGO assessments. For example, it is identified as "best choice" by the Seafood Watch reports produced by the Monterey Bay Aquarium.

Production system

In general, there is little information that describes in detail the production practices used in United States (for example, stocking rate, feed use, survivability, disease incidence, etc.) Most information comes from academic circles, most of whom have been involved in research on freshwater prawns in the United States and in other regions of the world. The production of freshwater prawns in the United States faces a serious disadvantage as the growing season is limited to 100 to 150 days, depending on precise location. In tropical countries, continuous production is feasible as water temperatures remain sufficiently high to maintain breeding, PL and grow-out populations. Water temperatures dictate stocking and harvesting dates. Temperature strongly affects the metabolism of freshwater prawns influencing dissolved oxygen consumption in feed intake. The ideal temperature in tropical conditions is considered to be between 28 and 31°C, although good growth has been observed at lower temperatures. The lowest temperature they can tolerate is 25°C. It is generally understood that growth rate is faster as temperature increases.

Because of the limitations of water temperature, production in United States is confined to batch culture, that is, a single stocking at the beginning of the season and total harvest before the temperature gets too cold.

The hatchery phase usually begins four months before stocking production ponds with juveniles. This allows enough time for the hatched eggs to produce larvae and for these to metamorphose from PLs into juveniles. The broodstock used tend to be adults collected during the autumn harvest. Spawning is relatively easy to initiate without environmental modification. Hatcheries use recirculating systems where the larvae are raised in tanks. These tanks need the supplementation of artificial light as larvae actively feed by sight. The period from egg hatch to harvest of PL requires 28 to 30 days. In the United States, freshwater prawn production involves an important intermediate nursery stage between the rearing of larvae and the grow-out stage. Consequently, as the water temperature in production ponds is critical, there is usually only a short window of about one month to initiate successful hatcheries before the PLs are entered into nurseries for 45 to 60 days. There is no room for mistakes as production will be reduced considerably if juveniles of sufficient size are not available when the water temperature is amenable. PLs are reared to juvenile status in indoor tanks.

It is critical that the juveniles are sufficiently large to cope with pond conditions when they are stocked in grow-out ponds. Also, with fewer production days in the US, the juveniles need to be larger. In this intermediate stage, the PL are grown at relatively high densities to metamorphose into juvenile prawns. The development of nurseries facilitates a much longer grow-out period and higher yields, in effect giving the juveniles a head start. Without nursery facilities, freshwater prawn production would not be commercially feasible in United States.

The nursery stage also enables growers to implement size grading - the culling of larger, faster growing juveniles to ensure that those that are entered into production ponds are even sized. This has been shown to increase the mean harvest size and total pond production in temperate climates. Survival rate in nurseries will vary, although it is generally 65 to 75%. The longer they are kept in the nursery, the more likely there are losses to cannibalism.

In the central United States, water temperatures normally allow for production in ponds for 120 to 140 days per year. Consequently, juveniles need to be approximately 0.3 to 0.5 gram to ensure that they reach a marketable size of between 20 to 30 g.

The water temperature constraint limits harvest to a 4 to 8 week period at the end of the production season. As a result, the supplies of all producers in a region appear on the market at the same time, posing serious local marketing challenges.

In some cases inter-cropping has been successful using the winter ponds for other species (such as trout). However, great care must be taken in ensuring that undesirable, predacious fish are not in the pond before the next crop of juvenile programs is stocked. Also, there have been various attempts to combine additional species with prawns, although most of these have been experimental.

In the US, stocking densities are usually lower than they would be in tropical climates. High density will reduce growth and survival; indeed, there is an inverse relationship between stocking density and mean prawn weight at harvest. Lower stocking densities reduce the risk of low dissolved oxygen and associated diseases. At warm temperatures, aeration is required to ensure that dissolved oxygen concentrations do not fall below 3 mg/L (ideally it should be 5 mg/L or above). If biomass is greater than 200 to 250 kg per hectare growth rate can only be maintained with feeding. Catfish feed is used to supplement the natural productivity of pond water, although fertilization may be used with careful attention to quantity, frequency and timing.

Harvest must take place before water temperatures drop below 70°C. While there are strong pressures to spread the marketing season by selective harvesting, it is often much easier to undertake total harvesting of batch production by creating a catch basin within a drained pond. This is an important consideration when constructing a freshwater prawn pond. The pond design should facilitate end of season draining that collects water flow into this basin from which the animals are harvested. Alternatively, an external catch basin can be part of the pond construction, allowing the entire product to flow out of the pond into a depression for harvest. The catch basin has to be of sufficient depth to avoid oxygen deficiencies. Where sales to live markets are required, it is necessary to purge the freshwater prawns in clean, aerated holding tanks. Chill killing at pond side ensures the best quality for sale – this involves immersing the animals in a mixture of ice and water (although this procedure must be carried out with great care to avoid any food safety issues arising because of inadequate chilling).

It is normal to differentiate a range of production practices from the extensive, low input methods to those which involve the application of more challenging methods based on what is known from freshwater prawn research. The former extensive system involves stocking densities from 8 to 12 thousand juveniles per acre and feed is usually not required, although supplementary organic fertilization is recommended to provide nutrients. This is more appropriate for the production in larger ponds used by ex-catfish growers on the flat lands in the Mississippi Delta. The latter, more intensive system involves greater attention to detail, such as pond preparation, size grading, the use of substrates (that provide increased surface area within the pond upon which the freshwater prawn can live), aeration, and higher levels of nutritionally dense feed (particularly later in the grow-out phase when high-quality commercially available catfish feed may be used). Semi-intensive stocking densities involve 15 to 18,000 juveniles per acre. A few producers stock at rates in excess of 18,000 juveniles per acre. The more intensive systems are appropriate to areas that are more northerly, where the production period is shorter and where ponds are smaller.

There is little data describing the use of these different approaches, although most producers are likely to adopt a less intensive approach as the investment and operating costs are much lower. However, in general, the production of freshwater prawn is dominated by relatively small-scale operations and consequently low input systems are widely recommended as more manageable and environmentally friendly. There is some research evidence that correctly applied, more intensive management approaches can result in better returns.

Freshwater prawns suffer some of the health issues associated with pond culture although rarely as seriously. As with other species, water quality parameters play an important role in determining the health status of freshwater prawns and their vulnerability to disease. As with all aquaculture, the avoidance of stress is critical to good animal health.

Good water quality is a major contributor to good health and performance. In particular, daily monitoring of dissolved oxygen and pH is essential throughout the production season. The ideal water conditions for freshwater prawn production are as follows:

Temperature	25-32°C
Salinity	0
Transparency	25-40 cm
Alkalinity	20-60 mg/L
Hardness	20-150 mg/L
pH	7.0-8.5
Un-ionized ammonia	0.1-0.3 mg/L
Dissolved oxygen	3-7 mg/L

Sudden loss of dissolved oxygen can occur quickly in high temperatures and can cause stress that reduces growth and even cause mortality. Consequently, the availability of aeration is essential. Variations in pH can be serious in the hottest part of the day and these can generate algal blooms that remove CO_2 from the water. There can be serious impacts causing high mortality at the early stages in the grow-out stage. Various management actions are recommended such as adding dyes to reduce plant photosynthesis and growth, and the use of safe chemical treatments. Adding herbicides is not recommended because of the environmental issues associated. Adding herbivorous fish to crop algae can reduce photosynthesis.

Ideally, a properly constructed and protected well is an ideal water source. In general this reduces microbial or chemical contamination, although the quality of water should be checked. Ponds fed by streams, reservoirs or other watershed sources are more vulnerable to contamination and are considered risky as there is no control over chemical or microbial contamination (such as animal waste). They are also more vulnerable to drought.

There is no recent data published on freshwater prawn production costs and returns. Feed costs are by far the largest operating cost for the most intensive production systems, although feed use is relatively modest compared with other species found in the United States.

Finally, the production methods usually involve the release of wastewater for maintaining water quality and also for harvest. As more US freshwater prawn farms have output that is less than 100,000 pounds per year they are not considered a Concentrated Aquaculture Animal Production (CAAP) facility under federal regulations and therefore do not require discharge permits. However, various states do require permits before commercial cultivation of freshwater prawns can take place and these permits may require careful management of wastewater disposal.

Length of production cycle

In the United States, there is only one crop cycle each year.

Key factors affecting success

The factors affecting success in farming freshwater prawns similar to other forms of aquaculture conducted in ponds. Critically, attention must be given to stocking intensity, water resource management, pond design, nutrition and harvest. As with most aquaculture, more intensive production systems are associated with greater production risk. These systems demand greater attention to water quality, stocking density, and feeding. US production cannot compete with imported supplies from areas which grow year-round freshwater prawn in a tropical climate. Consequently, the future depends upon a marketing effort that stimulates demand and premium prices for a local product produced in an environmentally responsible manner.

Perils

Freshwater prawns are subject to many of the problems of pond aquaculture in United States. Mortality may be caused by lack of dissolved oxygen, diseases, and predators. As prawns tend to stay on the bottom of ponds or on artificial substrates, they are less visible to predators. Predator losses are higher in shallow ponds, especially from wading birds. Predation does occur from raccoons, muskrats, turtles and some frogs. However, disease problems are minimal in the United States. The worst disease outbreaks have occurred in tropical climates, and China, the world's largest producer, has suffered several disease setbacks. These outbreaks are likely to be related to the growing intensification of production in tropical regions.

There is no information on the incidence of key diseases in United States, although there are few reports of any disease outbreaks of concern. Various bacterial diseases may affect freshwater prawn, including the *facultative* bacterium, although this is rare, not lethal and has little serious impact on performance. This disease is also associated with other common bacteria found in ponds such as *vibrio*, *pseudomonas*, and *aeromonas*, although none of these is reported as serious problems in the United States. The bacteria are found externally on shells that are subject to molt. Freshwater prawns have the capacity to carry the pathogens which result in losses in marine shrimp (*Litopenaeus vannamei*, *formerly Penaeus vannamei*). However, research has shown that the deadly whitespot syndrome virus (WSSV) and Taura Syndrome Virus (TSV) introduces no mortality in freshwater prawns.

Although it is difficult to confirm this, we suspect that the issue of dissolved oxygen depletion represents the most serious peril for freshwater prawn producers. This peril can be monitored and managed by the freshwater prawn farmer.

In addition, there are catastrophic losses from natural weather events such as floods and storms. Drought can also have a serious impact, especially where water originates from watershed sources. There are no data available on the incidence of these perils.

Classification of perils

The catastrophic perils can be differentiated from those that are subject to producer management influence. The former are insurable the latter are not.

Crop insurance issues:

- Multiple inventory assessments would be required to identify a baseline from which to measure loss. As with any aquaculture production in ponds, there is a major challenge identifying fish inventory at any point in time. There are likely to be high levels of inaccuracy in inventory estimates. This is particularly true for freshwater prawns. It would be necessary to record accurate counts of juveniles entered into ponds after size grading, and sound management practices will be required to ensure that cannibalism is limited and good water quality is maintained to reduce the incidence of disease. Also, it is difficult to identify standard growth ratios to assess inventory because of the range of conditions and management practices under which freshwater prawns are grown.
- In general, the freshwater prawn industry comprises growers operating on a relatively small scale. In recent years, the sector has attracted a number of operators that are relatively new to the sector and may lack full awareness of the procedures required for best management practices. Comprehensive record keeping of pond entries, feed or fertilization practices, and mortalities are unlikely to be available.
- 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).
- 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.
- There is a lack of a wide range of data required for actuarial assessment. For example, there is no clear data describing the structure of the industry, basic production data, the use of production practices, the incidence of disease or other perils, the normal level of mortalities, or prices when sold locally at pondside or in local farmers markets. Local prices can vary substantially from year-to-year depending on the level of local supply. There are also no data 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. These problems are more severe for freshwater prawn production than for some other species grown on a larger scale in ponds.

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 an appropriate 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, which follows this one, we review each of these issues for the 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. Several have covered 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.
  - **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.

- **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 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

	Catfish	Trout	Tilapia	Hybrid striped bass	Large mouth bass	Fresh water prawns	Comment
The size of the industry	✓	✓	✓	?	✗	✗	Catfish, trout, and tilapia are the three largest aquaculture of the species reviewed, sectors with sufficient size to justify interest in a crop insurance product (roughly $400, $63, and $55 million respectively). Each of these sectors face a challenging competitive situation and the prospects for halting the current decline in output of catfish and trout are limited. Hybrid striped bass probably has sufficient size to justify investment in a crop insurance plan (both roughly $30 million). The other species are all very small farm production sectors (less than $15 million). For example, of all the 124 agriculture and horticultural crop categories identified in the Crop Values 2010 report issued by the National Agricultural Statistics Service (NASS), only 11 had a value of less than $15 million.
The structure of the industry	✓	✓?	✓?	✓?	✓	✓	Catfish would appear to have a structure which is amenable to the development of the crop insurance program. The sector is geographically concentrated, systems of production are similar, all being based on ponds, and all production is destined for food production. Trout is much more geographically diverse, although most production is conducted in raceways. While most trout production is destined for food use, some production is for recreational use or restocking public and private waters. The industry in Idaho (representing roughly 70 to 75% of total production) is characterized by high levels of concentration of ownership. Tilapia companies are mainly using RAS, although there is some pond production in southern states. Tilapia production is widely distributed throughout the country, although a small number of larger companies supply a large and increasing share of the market. While most farms supply the live market, the configuration and engineering of these facilities varies considerably. The production of hybrid striped bass for food is concentrated in Texas among a relatively small number of specialist growers; however, the species is also raised in many other states. The freshwater prawn sector is dominated by small-scale operators, most of whom sell their product from their farms.

	Catfish	Trout	Tilapia	Hybrid striped bass	Large mouth bass	Fresh water prawns	Comment
The current and anticipated future status of the industry	✗	✗	✓	✓	?	?	Much of US aquaculture is under considerable competitive pressure, although prices at the time of writing are elevated because of short-term global supply shortages. All of the species sectors that we have reviewed are contracting with the possible exception of tilapia (and even here the data is anecdotal). Where US aquaculture competes with commodity products (e.g. trout, and catfish) it's margins are squeezed by the availability of imported product. For some species, it is possible to develop niche markets that offer premium prices (e.g. local or live markets). A number of new larger scale investments in RAS involve species that have not been candidates in this feasibility study. These are characterized by a very small number of producers, and in some cases single companies (e.g. yellow perch, barramundi coho salmon, and sturgeon). Several of these species have an opportunity to develop niche markets, although, as yet, there are very few success stories.
The availability of price information	✓	✗	✗	✗	✗	✗	Publicly available and reasonably representative price information is only available for catfish.
Availability of industrial production history	✓	✓	✓	✓?	✗	✗	Industry level production history is available for trout and catfish from regular documentation of the industry over an extended period. However, these data do not describe some key characteristics of the industry nor do they describe the variability in individual performance. Most major trout and catfish farms involved in food production are likely to have good records of fish introduced, fish harvested, and feed consumed. Production history from tilapia farms is likely to be available as the RAS would demand careful monitoring of inputs and outputs. Data for the other species is likely to be available although some less formal operations are unlikely to maintain an adequate level of record-keeping for crop insurance purposes. This is particularly true of freshwater prawns where production is mainly sold at pond side. No individual farm production history is available for any species to provide an indication of the variability in either production or mortality risk.
Availability of variability of individual performance or practices	✗	✗	✗	✗	✗	✗	

	Catfish	Trout	Tilapia	Hybrid striped bass	Large mouth bass	Fresh water prawns	Comment
The availability of represent-ative data that identify the performance of a species in a particular production system	✓	✓	✗	✗?	✗	✗	In general, catfish and trout have data that provide some indication of yields, although many of these data are not available by state because of confidentiality restrictions. For all other species, basic industry data on production levels, etc., is compiled anecdotally. There is some data available for the other species from irregular academic studies although much of this is dated. The hybrid striped bass sector is subject to a regular annual survey of leading producers and state aquaculture observers.
The availability of represent-ative 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 narrow geographical boundary and are unlikely to be representative of national enterprise costs and revenues. Some species associations (e.g. the hybrid striped bass association) provide estimates of costs and revenues on either an annual or an irregular basis. These are not assessed on a formal and systematic basis. In general, there is not the same intensity of study of aquaculture costs and revenues as might be found in crop agriculture.

	Catfish	Trout	Tilapia	Hybrid striped bass	Large mouth bass	Fresh water prawns	Comment
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). However, the availability of data that describe the incidence of these and other perils in aquaculture is limited for most species, although occasional academic studies have reviewed the status of individual sectors. Trout and catfish are subject to regular collection of data, and these data provide a broad picture of the most important perils. Critical detail (e.g. the specific disease peril and its impact) has been absent although a soon-to-be published report on catfish production practices provides useful data on mortality events. We have collected some of this information in the profiles of different species. The evidence suggests that disease and parasites (often interrelated) represent the most important perils facing all species and all production systems in aquaculture, although predation is a major issue for pond systems. Some diseases are highly infectious and unless appropriate precautions are taken they can be quickly transmitted among different containment structures on the same operation. Drought and flood have relatively low incidence (at least as identified for catfish and trout where empirical data are available), although their impact is regionally concentrated and may be serious in any given year (such as 2011 for catfish). However, long term drought and the growth in water demand is seriously threatening water supplies in several regions.
The availability of data on normal mortality	✓	✓	✓?	✓?	✓?	✓?	Estimates of normal mortality are available for all species from a number of academic and industry sources. However, there is likely to be substantial variation by species, production system, and location. Most data refer 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 fingerlings involve the greatest losses of individuals (this varies by species, but may be a high proportion of the original population). The grow-out period may also be represented by several different stages. As the density of production increases, fish of different sizes may need to be separated into other containment structures.

	Catfish	Trout	Tilapia	Hybrid striped bass	Large mouth bass	Fresh water prawns	Comment
							Mortality tends to be higher at the initial stages of grow-out when young fish 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 all species reviewed. However, as noted above, apart from catfish, there is little empirical data on the incidence of those perils. Disease and parasites appear to be the most important perils affecting aquaculture production, although predation and loss of dissolved oxygen can be major issues in pond systems.
The ease with which the size of the losses can be identified	✗	?✗	?✗	✗	✗	✗	Various alternative methods of measuring inventory are used within the industry. Most of these are associated with relatively high levels of error. As yet, no technological advances 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. These difficulties are amplified by practices such as multiple batch production and stocking ponds with other species. Finally, there may be a lack of clear evidence of mortality (e.g. when dead fish sink rather than float, or because of cannibalism). Raceways, RAS, and net cages offer better opportunities to measure inventory, although detailed record keeping is required. Even then, close observation and recording of a loss event is required. Consequently, inventory assessment is easier for trout produced in raceways, tilapia in recirculating systems, and trout when in net cages. Inventory assessment for the other species reviewed 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. Perils that result in acute losses are more appropriately included in crop insurance plans. All reviewed species are subject to diseases that can inflict acute loss and high levels of mortality.

	Catfish	Trout	Tilapia	Hybrid striped bass	Large mouth bass	Fresh water prawns	Comment
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. The limited availability of this independent specialization and expertise on a national basis would be a cause of concern for insuring some species. It is worth underlining here that aquaculture is a relatively new commercial activity, especially when undertaken on an intensive basis. There is not the same body of knowledge available compared with animal agriculture or crop production. This applies to key supporting sciences such as genetics and breeding, physiology, fish health, nutrition, etc. The gradual development of a firm scientific understanding will eventually lead to more precise and accurate identification of cause of loss in each of the species under review.
The extent to which management affects the impact of perils and losses	✘	✘	✘	✘	✘	✘	In general, the quality of management influences the incidence of a wide range of perils, and in particular potential pest and disease risks. Good management practice will involve constant attention to the water medium in which fish are being grown. Poor procedures can result in various disease issues, and poor performance. Sound organizational practices can also reduce the risk of disruption of production. The physical configuration of an aquaculture operation represents an important contribution to risk. Sound management invests in high-quality engineering that reduces the risk of losses.
The risk of moral hazard	✘	✘	✘	✘	✘	✘	As noted above, various practices such as continuous stocking, the movement of stock, multi-year production and hidden mortality might affect inventory measurement. Inventory assessments are extremely difficult to make and the insureds would need to maintain very detailed records to confirm inventory at any point in the production cycle. Because of the challenges in identifying the level of inventory and scale of loss, there is risk of moral hazard.

	Catfish	Trout	Tilapia	Hybrid striped bass	Large mouth bass	Fresh water prawns	Comment
The risk of adverse selection	✓	?✗	✗	?✗	✗	✗	As data on the aquaculture sector are very limited, there is a high risk of adverse selection when offering aquaculture insurance. This risk is reduced in sectors such as catfish where production is regionally concentrated and production systems are similar. While there is much data available on the trout sector, the production is widely distributed geographically and there is insufficient data on production in different regions to facilitate the identification of risk pools. In any case, the data available on the sectors failed to reveal the variability in production practices and performance. For the other species covered in this review, the absence of data for sound actuarial assessment threatens serious problems of adverse selection.
The availability of other risk management tools that might make an RMA plan redundant							See in rows below
A number of federal or state funded emergency programs	✓	✓	✓	✓	✓	✓	There have been several federal initiatives to assist agricultural producers because of disasters and all aquaculture producers can take advantage of NAP. Some aquaculture operations have been able to take advantage of both NAP and disaster assistance programs. We do not have access to data which will allow us to quantify the extent to which these programs are utilized. In any case, NAP provides coverage of only 27.5% of the value of crop, much less than would be provided by an RMA crop insurance program.
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).

	Catfish	Trout	Tilapia	Hybrid striped bass	Large mouth bass	Fresh water prawns	Comment
Availability of relevant futures markets	✗	✗	✗	✗	✗	✗	There is no opportunity to handle price risk through hedging on futures markets or through fixed price sales on contract to processors.
Other farm enterprises	?	?	?	?	?	?	There are no data describing the extent to which aquaculture activities are shared with other farm activities. It is feasible for aquaculture conducted under any production system to be incorporated into an existing farm business. Some aquaculture producers are vertically integrated to some extent providing some opportunity to handle risks at the production stage with other activities. This is more likely to be available to a few larger producers.
The availability and use of private insurance	✓	✓	✓?	✓	✓	✓	A small number of larger scale RAS enterprises that are funded by banks or private equity funds are required to seek insurance as a condition of financing. This is provided by brokers operating through foreign insurance companies that have some expertise in the aquaculture sector. However, this insurance cover is expensive as the insurance industry has little experience of these species and these types of operations in the US. Some larger trout industry participants have purchased private mortality insurance in the past. The only US insurer offering aquaculture insurance withdrew its aquaculture product five years ago.
The likely level of demand and willingness to pay appropriate premiums	?✗	✓?	?✗	?✗	?✗	?✗	There is no information available on the likely level of demand and willingness to pay for insurance. In general, there has not been an intensive effort to seek out crop insurance by any of the participants in the industry. When the proposals for catfish and trout plans were rejected by the FCIC Board there appears to have been little industry reaction through their associations. Few in the industry are aware of the initiative in the last Farm Bill that resulted in this study. The larger companies involved in trout production consider it too expensive and do not participate. The major stimulus for insurance has been the involvement of parties offering finance to aquaculture companies. With the exception of the larger RAS investments, traditional finance for aquaculture is supplied by the leading companies providing aquafeeds, or by the growers themselves. Feed companies have not insisted on crop insurance.

	Catfish	Trout	Tilapia	Hybrid striped bass	Large mouth bass	Fresh water prawns	Comment
The ease of defining units of production	✓?	✓?	?	✓?	✓	✓	In the previous review of aquaculture feasibility, a basic 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.
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 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.

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 aquaculture sector faces many perils, several critical factors argue against RMA developing industry plans. These are listed below.

- The small industry size for **freshwater prawns** and **largemouth bass** grown for food suggests that there will be little incentive for AIPs to participate in the program.
- There are severe serious 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**.
- The highly diverse **recirculating systems** used in **tilapia** production and 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.
- The challenge of measuring inventory and losses in **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, and the occasional application of certain practices in some species and on some operations. These practices include: continuous stocking of grow-out ponds; the use of other species for under-stocking; the movement of stock between ponds and/or facilities. Also, the lack of clear evidence of mortalities; cannibalism because of uneven stocking sizes or poor feeding; and, the mixing of different batches may frustrate accurate inventory measurement.
- Measurement systems that can be applied with some confidence are available for some **trout** facilities in **raceway systems**. However, even these are challenged by multiyear production and the occasional practice of regularly moving **trout** between different raceways and facilities to maximize efficient carrying capacity.
- In the **tilapia**, **hybrid striped bass**, and **trout** sectors, the number of commercial operations is very small with a large share of industry output in the hands of relatively few. This restricts the spreading of risk over a sufficient number of insureds.

- The availability and use of private insurance for some larger **RAS** investments implies that provision of crop insurance is already available to some in sectors using this system.
- The lack of critical data (e.g. on prices, causes of mortality, harvests, yields, losses, etc.) that frustrates solid actuarial analysis for **all species** necessitates rates that are likely to be far too high to result in industry participation.
- The lack of adequate data for sound actuarial analysis for **all species** could also lead to problems of adverse selection.
- While there is little evidence to base conclusions on willingness to pay, **no species** sector is pushing hard for crop insurance coverage.
- 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: **Catfish Production and Value Data**
Update frequency: Semi-annually (End of January/beginning of February and July)
Data available from: 1988-present
Description: State production and value data for each size group

- Food-size (large- greater than 3 pounds, medium- 1.5 to 3 pounds, small- ¾ of a pound to 1.5 pounds)
- Stockers (large- fish weighing over 180 pounds to 750 pounds per 1,000 fish, small- fish weighing over 60 pounds to 180 per 1,000 fish or over 6 inches in length)
- Fingerlings and fry (fish weighing less than 2 pounds per 1,000 fish or less than 2" in length)
- Broodfish - Fish kept for egg production (3-10 pounds in size of 4-6 years in weight)

Source: USDA-NASS - Link
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1016

Title: **Catfish Processing**
Update frequency: Monthly
Data available from: January 1993- present
Description: Average Price Paid to Producer: refers to the price of fish delivered to the processing plant door. Price includes charges for any services provided by the processing plant, such as seining and hauling, but does not include any adjustments based on year-end settlements. Report on previous month's price paid to producers

- Fresh: Whole (round and gutted, whole dressed), Other (steaks, nuggets, other), Fillets
- Frozen: Whole dressed, Other (steaks, nuggets, other), Fillets

Source: USDA-NASS Link
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1015

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
- Tilapia (unspecified)
- Catfish (unspecified)

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:

- Domestic catfish, whole dressed- headed and gutted, fresh and frozen
  - Sizes: 3-5oz, 5-7oz, 7-9oz
- Domestic catfish, Boneless skinless fillets, fresh and frozen
  - Sizes: 3-5oz, 5-7oz, 7-9oz, 9-11oz
- Domestic catfish, Value-added (breaded fillets, breaded strips or fingers, steaks, and nuggets), fresh and frozen
- Imported sea trout from Argentina/Uruguay in layers or shatter packs
  - Sizes 1-4oz, 4-6oz, 6-8oz

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: **Trout Production**
Update frequency: Annually
Data available from: 1988- present
Description: State and national production and value data (average price per pound) for each of the following size groups

- Foodfish 12" or longer
- Foodfish 6"-12"
- Foodfish 1"-6"

Source: USDA-NASS Link
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1172

Title: **Hybrid Striped Bass Industry Update**
Update frequency: Annually
Data available: 1986- present
Description: Annual report on US production of hybrid striped bass by region, production system type, live or on-ice and average prices received.

- Regions: Northeast, Mid-Atlantic, Southeast, Midwest, West and nationwide
- Farm-gate: on-ice and live
- Live: on-ice and live

Source: Data compiled by the Hybrid Striped Bass Growers Association from participating farmers.

APPENDIX 2: BIBLIOGRAPHY

Catfish

Bennet, D. (2007, May 23). *Research showing worth of hybrid catfish*. Retrieved 2011, from Delta Farm Press: http://deltafarmpress.com/research-showing-worth-hybrid-catfish

Durborow, R.; Wise, D.; Terhune, J. (2003). *Saprolegniasis (Winter Fungus) and Branchiomycosis of commercially cultured channel catfish*. Southern Regional Aquaculture Center Publication No. 4700.

FAO Cultured Aquatic Species Information Programme. (2010). *Cultured aquatic species information programme: Ictalurus punctatus*. http://www.fao.org/fishery/culturedspecies/Ictalurus_punctatus/en

Hanson, T.; Sites, D. (2010). *2009 US Catfish Database*. Mississippi State Department of Agriculture Economics.

Hanson, T. (2011). *US Catfish Industry Update*. Presentation at Catfish Farmers of America (2/17-19/2011), Mobile, Alabama.

Ish, T.; Doctor K,. (2005). *Seafood Watch: Channel catfish, US farmed*. Monterey Bay Aquarium.

NASS, USDA. (Various years). *Catfish Processing*. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1015

NASS, USDA. (Various years). *Catfish Production*. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1016

NASS, USDA. (2010). *Catfish production part 1: Reference of catfish health and production practices in the US, 2009*. http://www.aphis.usda.gov/animal_health/nahms/aquaculture/index.shtml

NASS, USDA. (unpublished). *Catfish production part II: Health and production practices for foodsize catfish in the US, 2009*.

Tucker, C.; Avery, J.; Engle C.; Goodwin, A. (unpublished). *Industry profile: Pond-raised channel catfish*. USDA, RMA, FCIC, Mississippi State University.

Freshwater Prawn

Coyle, S.; Tidwell, J.; et al. (2003). *A comparison of two feeding technologies in freshwater prawns, raised at high biomass densities in temperate ponds*. Journal of Applied Aquaculture, 125-135.

D'Abramo, L.; Ohs, C.; et al. (2003). *Culture of freshwater prawns in temperate climates: management practices and economics.* Mississippi Agricultural and Forestry Experiment Station.

D'Abramo, L.; Silva, J., Frinsko.; M. (2009). *Sustainable farming of freshwater prawns and the assurance of product quality*. Mississippi Agricultural and Forestry Experiment Station. Bulletin 1188.

Dasgupta, S. (2005). *Economics of freshwater prawn farming in the United States*. Southern Regional Aquaculture Center Publication No. 4830.

FAO Cultured Aquatic Species Information Programme. (2010). *Cultured aquatic species information programme: Macrobrachium rosenbergii*.
http://www.fao.org/fishery/culturedspecies/Macrobrachium_rosenbergii/en

Flick, G. (2011). *Post-harvest quality of freshwater prawns*. Global Aquaculture Advocate, p. 60-62.

Galitzine, V. (2009). *Seafood Watch: US farmed freshwater prawn*. Monterey Bay Aquarium.

Mississippi State University Extension Service. (1998). *Freshwater prawns hatchery & nursery management.*

Mississippi State University Extension Service. (2003). *Freshwater Prawns Pond Production and Grow-out.*

New, M.; Wagner, V.; et al. (2009). *Freshwater prawns: biology and farming*. Wiley-Blackwell: Oxford.

New, M. (2002). *Farming freshwater prawns, a manual for the culture of giant river prawns*. FAO Fisheries Technical Paper 428. FAO: Rome; p. 212.

Posadas, B. (2003). *Economic and marketing considerations of freshwater prawn production in the US*. Presented at Aquaculture America 2003. (2/18-21, 2003). Mississippi State University, Coastal Research and Extension Center and Sea Grant Mississippi State University.

Ziaei-Nejad, S.; Rafiee, G.; Shakouri, M. (2009). *Culture and breeding of freshwater prawn as an exotic species in Iran, present status and future perspective*. Department of Fisheries, Iran. Presented at Asian Pacific Aquaculture 2009.

Spotts, D. (1981). *Introducing Macrobrachium rosenbergii*. Retrieved 2011, from Miami Aqua-culture, Inc.: http://www.miami-aquaculture.com/sm%20scale%20macrobra.htm

Tidwell, J. (2010). *Prawn (freshwater shrimp) culture*. In Encyclopedia of Animal Science, Second Edition, Edited by Ullrey, D; Kirk Baer, C; & Pond, W.

Tidwell, J.; D'Abramo, L. et al. (2005). *Overview of recent research and development in temperate culture of the freshwater prawn in the South Central United States*. *Aquaculture Research*, v. 36, p. 264-277.

Tidwell, J.; Coyle, S., et al. (2002). *KSU prawn production manual*. Kentucky State University Aquaculture Program.

Tiu, L. (2005). *Production of freshwater shrimp culture in Ohio*. OSU South Centers. Extension presentation

Treece, G. (2011). *The Texas aquaculture industry*. Texas A&M University and Sea Grant College Program. http://www.texasaquaculture.org/

Wurts, W.; Herron, R.; Coyle S. *Low-input shrimp (prawn) farming demonstration*. Kentucky State University Cooperative Extension Program. http://www.ca.uky.edu/wkrec/lowInputshrimpky.htm

Wurts, W. A. *Organic fertilization in culture ponds*. Kentucky State University Cooperative Extension Program. World Aquaculture, 64-65. http://www.ca.uky.edu/wkrec/OrganicFertilization.pdf

Hybrid Striped Bass

Carlberg, J. (2002). *U.S. production and sales of hybrid striped bass (1987-2002)*. Kent SeaTech Corporation presentation.

Carlberg, J.; Massingill, M.; Van Olst, J. (2008). *Twenty-one years of hybrid striped bass culture in the US*. Kent SeaTech Corporation presentation.

D'Arbramo, L.; Frinsko, M. (2008). *Hybrid striped bass: pond production of food fish*. Southern Regional Aquaculture Center Publication No. 303.

Dunning, R.; Daniels, H. (2001). *Hybrid Striped Bass Production in Ponds: Enterprise Budget.* Southern Regional Aquaculture Center Publication No. 3000.

Hodson, R. (1989). *Hybrid Striped Bass: Biology and Life History*. Sothern Regional Aquaculture Center Publication No. 300.

Kohler, C. C. (2000). *A white paper on the status and needs of hybrid striped bass aquaculture in the North Central Region*. North Central Regional Aquaculture Center.

Kohler, C. C. (2004). *A white paper on the status and needs of hybrid striped bass aquaculture in the North Central Region.* North Central Regional Aquaculture Center.

Lougheed, M.; Nelson, B. (2003). *Hybrid striped bass production, markets and marketing*. North Central Regional Aquaculture Center.
http://www.extension.org/mediawiki/files/4/42/Hybrid_Striped_Bass_Production,_Markets_and_Marketing.pdf

Lovshin, L. (2001). *Culture of hybrid striped bass in the US*. Department of Fisheries and Allied Aquacultures, Auburn University, Alabama, USA. PowerPoint presentation.

Ludwig, G. (2004). *Hybrid striped bass: fingerlings production in ponds*. Southern Regional Aquaculture Center Publication No. 302.

McGinty, A.; Hodson, R. (2008). *Hybrid striped bass: hatchery phase*. Southern Regional Aquaculture Center Publication No. 301.

Morris, J.; Kohler, C.; Mischke, C. (1999). *Pond culture of hybrid striped bass in the North Central Region*. North Central Regional Aquaculture Center.

O'Neill, B. (2005). *Seafood Watch: US farmed hybrid striped bass*. Monterey Bay Aquarium.

Smith, S. (2010). *Common disease of cultured striped bass and its hybrids*. Virginia Cooperative Extension. Publication 600-080.

Turano, M. J. (2010). *US hybrid striped bass production: 2010 Industry Update*. Striped Bass Growers Association presentation.

Turano, M. J. (2011). *US hybrid striped bass production: 2011 Industry Update*. Striped Bass Growers Association presentation.

Largemouth Bass

Conte, F.; Waldvogel, J.; Vaight, T. (2001). *Fish stocking strategies for largemouth bass in recreational ponds and lakes*. University of California, Davis. http://aqua.ucdavis.edu/DatabaseRoot/pdf/ASAQ-C14.PDF

Heidinger, R. (2000). *A white paper on the status and needs of largemouth bass culture in the North Central Region.* North Central Regional Aquaculture Center. http://aquaculture.davis.wvu.edu/r/download/43832

Bowker, J.; Bowman, M.; et al (2009). *Controlling mortality caused by external Columaris in largemouth bass using common antiseptics*. Presentation at the 139th Annual AFS Meeting (8/30- 9/4, 2009), Nashville, TN.

Kilpatrick, K. *Natchitoches, National Fish Hatchery*. US Fish and Wildlife Service.

Tidwell, J.; Coyle, S.; Woods, T. (2000). *Species Profile, Largemouth Bass*. Southern Regional Aquaculture Center Publication No. 722.

Tidwell, J. (2008). *Development of efficient aquaculture technologies for the largemouth bass*. Kentucky State University Publication No. 722.

Tilapia

Auburn University and USDA-NRCS. (2004). *Managing systems for tilapia culture*. BMP No. 17.

Burdass, M. (2010). *Tilapia husbandry*. Centre for Environment, Fisheries & Aquaculture Science, UK, http://www.slideshare.net/Cefas/tilapia-husbandry.

Bordevik, M., Froystad-Saugen, M., et al. (2008). *Francisella Sp. An emerging disease problem for the global fish farming industry?*. Pharmaq.

Cedric, K., Lauke, L., et al (2004). *Emerging diseases in tilapia: future prevention methods will alleviate the economic threat.* Intervet Norbio Singapore

DeLong, D., Losordo, T., Rakocy, J. (2009). *Tank culture of tilapia.* Southern Regional Aquaculture Center Publication No. 282.

Dunning, R., Losordo, T., Hobbs, A. (1989). *The Economics of Recirculation Tank Systems: A Spreadsheet for Individual Analysis*. Southern Regional Aquaculture Center Publication No. 456.

FAO Cultured Aquatic Species Information Programme. (2010). *Cultured Aquatic Species Information Programme: Oreochromis niloticus*. http://www.fao.org/fishery/culturedspecies/Oreochromis_niloticus/en

Fitzsimmons, K. (2010). *Around the world with Fitz*. Western Regional Aquaculture Center, Waterlines Winter 2010, p. 4-6.

Fitzsimmons, K. (2008). *Global Update 2008: Tilapia Production, Innovations, and Markets*. Presented at Aquaculture America, Feb. 2008, Orlando, FL.

Fitzsimmons, K. (2010). *Potential to increase global tilapia production*. Presented at Global Outlook for Aquaculture Leadership, Kuala, Lumpur.

Fitzsimmons, K. (2011). *Tilapia 2011- Swimming against the tide: increased consumption in a down market.* Presented March 2011, New Orleans, LA.

Fitzsimmons, K. (1999). *Tilapia aquaculture in the 21st century. University of Arizona*. Presentation.

Fitzsimmons, K. (2009). *Tilapia production, market report: production, consumption Increase despite economic downtown*. Global Aquaculture Advocate, 67-70.

Fitzsimmons, K. (2007). *Tilapia quality and safety in global markets*. Presented October 2007, Honolulu, HI.

Fitzsimmons, K. (2011). *Tilapia-2010: Industry continues to gain importance*. Presented January 2011, Kochi, India.

Fitzsimmons, K., Naim, S., Alghanim, K. (2010). *Tilapia: 2009 state of the industry*. Presented at WAS, March 2010, San Diego, CA.

Macintosh, D. J. (2010). *Risks associated with using methyl testosterone in tilapia farming*. media.sustainablefish.org/MT_WP.pdf

McAndrew, B. (2009). *Tilapia research institute of aquaculture*. Presented at Centre for Environment, Fisheries & Aquaculture Science, UK tilapia workshop, June 2009.

McGinty, A., Rakocy, J. *Cage Culture of Tilapia*. Southern Regional Aquaculture Center Publication No. 281.

Roderick, E. (2009) *Tilapia – a global commodity, the 'aquatic chicken' comes of age*, http://www.slideshare.net/Cefas/a-global-outlook-for-tilapia-and-the-potential-for-growth-in-the-uk-tilapia-industry-2374017

Popma, T., Masser M. (1999). *Tilapia: life history and biology*. Southern Regional Aquaculture Center Publication No. 283.

Rakocy, J.; McGinty, A. (1989). *Pond culture of tilapia*. Southern Regional Aquaculture Center publication no. 280.

Stinton, N. (2010). *Biosecurity for the tilapia industry*. Presentation, Centre for Environment, Fisheries & Aquaculture Science, Fish Health Inspectorate, Cefas Weymouth Laboratory, Weymouth, Dors.

Tetreault, I. (2009).: *Seafood Watch: farmed tilapia*. Monterey Bay Aquarium.

Watanabe, W.; Losordo, T.; et al. (2002). *Tilapia production systems in the Americas: technological advances, trends and challenges*. Reviews in Fisheries Science, pp. 465-498.

Wendover, N., Wardle, R. (2009). *Tilapia farming common diseases and health management*. Intervert.

Western Edge. (2007). *The tilapia handbook, a learning guide to the farming and production of tilapia*.

Trout

Engle, C.; Pomerleau, S.; et al. (2005). *The economic impact of proposed effluent treatment options for production of trout in flow-through systems*. Aquaculture Engineering 303-323.

FAO Cultured Aquatic Species Information Programme. (2010). *Cultured Aquatic Species Information Programme: Oncorhynchus mykiss. http://www.fao.org/fishery/culturedspecies/Oncorhynchus_mykiss/en*

Hinshaw, J.; Fornshell, G.; Kinnunen, R. (unpublished). *A profile of the aquaculture of trout in the United States*. USDA, RMA, FCIC, Mississippi State University.

LaFrentz, B.; Cain, K. (2004). *Bacterial coldwater disease*. An extension bulletin for the Western Regional Aquaculture Center.

NASS. (2009). *Overview of the US trout industry*. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1819

NASS. (Various years). *Trout production*. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1172

O'Neill, B. (2006). *Seafood Watch: US farmed rainbow trout.* Monterey Bay Aquarium.

Wilkins, D. (2011). *Pumpers ask state Supreme Court to reconsider ruling*. Capital Press. http://www.capitalpress.com/newsletter/dw-water-appeal-042211

Recirculating systems

Aneshansley, E. (2009). *Systems part II: related industries*. Presented, Midwest RAS Workshop, June 2009.

Burdass, M. (2010). *The potential for recirculation aquaculture*. Presented for Sparsholt College Hampshire and Andover College prepared for life.

Boulet, D.; Struthers, A.; Gilbert, E. (2010). *Feasibility study of closed-containment options for the British Columbia aquaculture industry*.

Delabbio, J.; et al. (2005). *Fish disease and biosecurity: attitudes, beliefs, and perceptions of managers and owners of commercial finfish recirculating facilities in the US and Canada*. Journal of Aquatic Animal Health, 153-159.

Delabbio, J.; Murphy, B.; et al. (2004). *An Assessment of biosecurity utilization in the recirculation sector of finfish aquaculture in the US and Canada*. Aquaculture, p. 165-179.

Flimlin, G.; Buttner, J.; Webster, D. (2008). *Aquaculture systems for the Northeast*. Northeastern Regional Aquaculture Center.

Global Aquaculture Alliance. *The Advocate*. Various months

Good, C.; Davidson, J.; et al. (2009). *Evaluating rainbow trout performance, health and welfare at The Freshwater Institute*. USDA, ARS.

Killian, H. S.; Heikes, D.; et al. (1998). *Inventory assessment methods for aquaculture ponds*. Southern Regional Aquaculture Center Publication No. 395.

Hill, B. (2010). *Why is aquaculture and aquatic animal health so important?* OIE Workshop for Aquatic Animal Focal Points.

Manci, B. (2009). *Recirculating aquaculture systems for coolwater fishes*. Fisheries Technology Associates, Inc.

Masser, M., Rakocy, J., Losordo, T. (1992). *Recirculating Aquaculture Tank Production System: Management of Recirculating Systems*. Southern Regional Aquaculture Center Publication No. 452.

Myers, J., Govindasamy, R., et al (2007). *Consumer Analysis of Business Network Development for Ethnic Live Seafood Markets of in the Northeast Region*. http://www.state.nj.us/seafood/FINALEthnicLiveSeafood.pdf

Sharon McGladdery, G. K. *Trans-boundary Disease Surveillance for Delineation of Zones- the Canada-USA VHS Experience*. Canadian Food Inspection Agency.

Summerfelt, S. (2010). *Overview of Recirculating Aquaculture Systems in the US*. Conservation Fund Freshwater Institute. https://campus.uwsp.edu/sites/cols-ap/nadf/Workshops/Overview%20RAS%20in%20US.pdf

Timmons, N.; Timmons, M.; Ebeling, J. (2006). *Recirculating Aquaculture Systems (RAS) Technologies: Part 2*. Aquaculture Magazine Sept/Oct 2006.

Timmons M.; Ebeling J;(Author), Wheaton F; Summerfelt S; Vinci B, (2002), *Recirculating Aquaculture Systems, 2nd Edition, Northeastern Regional Aquaculture Center.*

Virginia Cobia Farms. (2009). *Industry Experience in Good Practice Recirculation Systems*. http://www.worldwildlife.org/what/globalmarkets/aquaculture/WWFBinaryitem14559.pdf

General aquaculture

APHIS, USDA. (2007). *Assessing Infectious Disease Emergence Potential in the US aquaculture Industry Phase I: US Aquaculture Industry Profile*. http://www.aphis.usda.gov/animal_health/emergingissues/

APHIS, USDA. (2007). *Assessing Infectious Disease Emergence Potential in the US aquaculture Industry Phase 2: Infectious Disease Emergence Qualitative Risk Assessment Tool: Development*. http://www.aphis.usda.gov/animal_health/emergingissues/

APHIS, UDSA. (2007). *Assessing Infectious Disease Emergence Potential in the US aquaculture Industry Phase 3: Infectious Disease Emergence Qualitative Risk Assessment Tool: Application and Results*. http://www.aphis.usda.gov/animal_health/emergingissues/

Bowker, J.; Trushenski, J. (2011) *Guide to using drugs, biologicals, and other chemicals in aquaculture*. FCS Working Group on Aquaculture drugs, chemicals and biologics.

FDA. *Approved drugs for use in aquaculture*. http://www.fda.gov/AnimalVeterinary/DevelopmentApprovalProcess/Aquaculture/ucm132954.htm

Losordo, T.; et al. (2010). *North Carolina Aquaculture Update*. NC State University.

Losordo, T.; et al. (2009). *North Carolina Aquaculture Update*. NC State University.

Nash, C. E. (2011). *The History of Aquaculture*. Wiley Blackwell.

NASS. (2006). *2005 Census of Aquaculture*. http://www.agcensus.usda.gov/Publications/2002/Aquaculture/index.asp

NASS. (2006). *2005 Census of Aquaculture, Volume 3, Special Studies Part 2*. http://www.agcensus.usda.gov/Publications/2002/Aquaculture/index.asp

National Aquatic Animal Health Task Force. (2008). *National aquatic animal health plan for the US*. USDA, Animal and Plant Health Inspection Service

Preston, N., Glencross, B. (2011). *Aquaculture global challenges and local solutions*. CSIRO Food Futures Flagship presentation.

Hall, S.J.; Delaporte A,; Phillips, M, Beveridge M,; O'Keefe, M. (2011). *Blue Frontiers, managing the environmental costs of aquaculture*. The WorldFish Center, Penang, Malaysia.

Stiles, M., Lahr, H., et al (2011). *Bait and switch: how seafood fraud hurts our oceans, our wallets and our health*. OCEANA. http://na.oceana.org.

U.S. Fish and Wildlife Service. (2011). *Approved vaccines for use in aquaculture.* USDA, APHIS, Aquatic Animal Drug Approval Program, AFS-Fish Culture Section, AFS Fish Health Section, American Veterinary Medical Association.

Minor Species

Halpin, P. (2005). *Seafood Watch: farmed crayfish*. Monterey Bay Aquarium.

Held, J.; Malison, G.; et al. (2009). *Production parameters and breakeven costs for yellow perch grow-out in recirculation aquaculture systems*. www.was.org

D'Abramo L. R., C. L. (2002). *Production of the red swamp crayfish in earthen ponds without planted forage: management and practices*. Mississippi Agricultural and Forestry Experiment Station Bulletin 1115.

McGivern, S.M (2009). *Seafood Watch: farmed US freshwater coho salmon*. Monterey Bay Aquarium.

Malison, J. A. (2000). *A white paper on the status and needs of yellow perch aquaculture in the North Central region*. North Central Regional Aquaculture Center.

Ng, C. (2008). *Seafood Watch: Great Lakes region*. Monterey Bay Aquarium.

Peet, C. (2006). *Seafood Watch: farmed barramundi*. Monterey Bay Aquarium.

Insurance

Anrooy, R., Secretan, P., et al (2006). *Review of the current state of world aquaculture insurance*. FAO Fisheries Technical Paper 493.

Aquaculture-Insurance Exchange. (2004) *Aquaculture insurance exchange benefits summary flier.*

Bondad-Reasntaso, M., Arthur, J. R., Subasinghe, R. (2008). *Understanding and applying risk analysis in aquaculture*. FAO Fisheries and Aquaculture Technical Paper 519.

FSA, USDA. (2009). *ELAP rules and regulations.*
http://www.apfo.usda.gov/FSA/webapp?area=home&subject=diap&topic=elap

FSA, USDA. (2009). *Emergency assistance for livestock, honeybees, and farm-raised fish program (ELAP).* http://www.apfo.usda.gov/FSA/webapp?area=home&subject=diap&topic=elap

FSA, USDA. (2009). *Noninsured crop disaster assistance program for 2009 and subsequent years- fact sheet.* http://www.fsa.usda.gov/Internet/FSA_File/nap09.pdf

Grannis, J.; Green, J.; Bruch, M. (2004). *Animal health: the potential role for livestock disease insurance*. APHIS, USDA. http://ageconsearch.umn.edu/bitstream/27972/1/03010001.pdf

Hanson, T.; Shaik, S.; et al. (2008). *Identifying risk factors affecting weather and disease-related losses in the US farm-raised catfish industry*. Agricultural and Resource Economics Review, p. 27-40.

Murray, L.; Murray, K.P.; et al. (2004). *A review of operating economics and finance research needs.* Northeastern Regional Aquaculture Center, NRAC Publication No. 03-004.

Shields, D.; Chite, R. (2010). *Agriculture disaster assistance*. Congressional Research Services.

APPENDIX 3: ACCESSIBILITY

This data is for figure 1 on page 9: Fish and crustacean production

Years are on the horizontal axis, million metric tons of production is on the vertical axis.

	Asia excl. China	China	ROWorld
1950	170,710	65,961	86,094
1951	179,898	117,193	83,119
1952	199,858	136,001	80,509
1953	216,552	182,000	87,493
1954	236,640	277,960	102,815
1955	263,333	319,058	106,962
1956	277,143	338,907	110,977
1957	289,743	564,807	119,785
1958	310,552	553,855	102,662
1959	333,474	596,310	120,367
1960	348,467	499,646	137,846
1961	374,902	349,178	156,342
1962	383,775	314,876	150,149
1963	398,099	360,000	161,542
1964	432,631	400,242	179,658
1965	459,282	514,452	201,800
1966	488,676	524,849	205,702
1967	517,225	500,227	223,989
1968	574,994	485,873	235,004
1969	598,577	546,914	236,251
1970	646,564	582,380	263,550
1971	704,079	620,536	274,073
1972	753,534	622,089	316,748
1973	822,484	659,478	338,107
1974	890,600	711,412	366,676
1975	940,117	754,019	417,727
1976	1,002,675	742,745	420,405
1977	1,077,805	775,389	444,032
1978	1,184,094	770,567	447,199
1979	1,307,932	822,804	474,276
1980	1,411,237	915,814	529,942
1981	1,619,592	1,029,383	638,927
1982	1,708,097	1,227,812	743,642
1983	1,869,888	1,455,492	802,101

1984	1,980,884	1,839,758	882,784
1985	2,115,749	2,433,617	951,914
1986	2,266,534	3,053,363	1,086,860
1987	2,581,357	3,666,836	1,196,590
1988	2,843,159	4,129,589	1,219,294
1989	3,006,576	4,388,920	1,373,618
1990	3,245,105	4,676,917	1,498,238
1991	3,572,805	4,892,653	1,433,273
1992	3,776,248	5,603,482	1,504,173
1993	3,980,691	6,632,127	1,520,590
1994	4,373,431	8,057,176	1,597,426
1995	4,651,480	9,650,993	1,769,737
1996	4,787,517	11,268,706	1,978,319
1997	4,994,208	11,867,317	2,211,029
1998	5,113,442	12,275,443	2,387,492
1999	5,644,812	12,984,023	2,668,485
2000	5,776,173	13,817,426	2,909,403
2001	6,330,793	14,567,026	3,242,864
2002	6,770,531	15,536,070	3,422,948
2003	7,577,034	16,000,925	3,655,710
2004	8,783,683	17,094,499	3,813,995
2005	9,574,927	18,211,118	3,980,609
2006	10,416,059	19,525,988	4,266,605
2007	11,111,000	20,792,041	4,458,961
2008	12,361,251	21,830,039	4,643,006

This data is for figure 2 on page 9: Chart showing the development of capture and all aquaculture output

Years are on the horizontal axis, million metric tons of capture and aquaculture output on the vertical axis. The data for 2009 and 2010 are estimates.

	Capture	Aquaculture
1950	19	1
1951	21	1
1952	23	1
1953	23	1
1954	25	1
1955	27	1
1956	28	1

1957	29	2
1958	29	2
1959	32	2
1960	34	2
1961	38	2
1962	41	2
1963	42	2
1964	47	2
1965	48	2
1966	51	2
1967	55	2
1968	58	2
1969	57	2
1970	63	3
1971	63	3
1972	59	3
1973	59	3
1974	62	3
1975	62	4
1976	65	4
1977	64	4
1978	66	4
1979	66	4
1980	67	5
1981	69	5
1982	71	6
1983	71	6
1984	77	7
1985	78	8
1986	84	9
1987	84	11
1988	88	12
1989	88	12
1990	85	13
1991	84	14
1992	85	15
1993	87	18
1994	92	21
1995	92	24
1996	94	27

1997	94	29
1998	88	30
1999	94	33
2000	96	35
2001	93	38
2002	93	40
2003	90	43
2004	94	46
2005	94	49
2006	92	52
2007	90	50
2008	90	53
2009e	90	54
2010e	90	56

This data is for figure 3 on page10: Chart showing the development of aquaculture

Years are on the horizontal axis, million metric tons of aquaculture output on the vertical axis. The data for years 2009 and 2010 are estimates.

	Aquaculture
1950	1
1951	1
1952	1
1953	1
1954	1
1955	1
1956	1
1957	2
1958	2
1959	2
1960	2
1961	2
1962	2
1963	2
1964	2
1965	2
1966	2
1967	2

1968	2
1969	2
1970	3
1971	3
1972	3
1973	3
1974	3
1975	4
1976	4
1977	4
1978	4
1979	4
1980	5
1981	5
1982	6
1983	6
1984	7
1985	8
1986	9
1987	11
1988	12
1989	12
1990	13
1991	14
1992	15
1993	18
1994	21
1995	24
1996	27
1997	29
1998	30
1999	33
2000	35
2001	38
2002	40
2003	43
2004	46
2005	49
2006	52
2007	50

2008	53
2009e	54
2010e	56
e = provisional	

This data is for figure 4 on page11: Chart showing top aquaculture producing countries share of global aquaculture production

This is a pie graph; each segment represents the percentage of production by a specific country.

Country	Percent of world production
China	61%
India	7%
Vietnam	4%
Indonesia	3%
Thailand	3%
Bangladesh	2%
Japan	2%
Chile	2%
Norway	2%
Rest of world	14%

This data is for figure 5 on page11: Chart showing the global production of species under review

Years are on the horizontal axis, million metric tons of a species is on the vertical axis.

	Giant river prawn	Whiteleg shrimp	Rainbow trout	Channel catfish	Atlantic salmon	Nile tilapia
1980	2,861	8,286	145,124	34,855	5,288	41,357
1981	3,884	11,054	158,599	68,200	10,108	45,773
1982	5,956	20,596	172,276	90,909	13,265	51,116
1983	7,495	33,584	181,724	98,300	20,638	60,434
1984	11,258	33,292	186,769	109,000	26,985	66,660
1985	10,090	30,677	197,305	122,853	38,797	89,989
1986	13,882	44,077	206,799	148,627	58,979	111,649
1987	24,058	69,664	227,848	169,091	67,146	124,413
1988	25,756	77,293	249,521	164,183	110,599	132,182
1989	26,483	78,205	259,161	182,838	168,063	203,198
1990	30,842	88,429	277,815	163,719	225,642	233,802
1991	37,554	119,709	287,294	177,373	266,283	257,912

1992	33,030	134,552	305,413	209,478	247,528	331,238
1993	29,164	108,892	318,976	210,127	305,610	382,365
1994	32,207	121,212	341,704	200,627	374,931	429,469
1995	35,535	141,778	377,929	202,970	465,245	524,162
1996	61,964	140,363	402,690	215,667	551,906	628,979
1997	66,627	172,568	455,829	238,786	646,516	709,832
1998	82,058	193,576	472,446	257,523	688,227	723,970
1999	101,509	186,743	454,808	272,280	805,616	825,215
2000	130,689	146,362	491,927	271,309	895,808	970,689
2001	171,617	269,412	549,583	273,277	1,030,005	1,033,672
2002	168,236	475,363	543,800	289,154	1,086,134	1,115,585
2003	167,519	984,624	550,469	342,316	1,147,682	1,271,922
2004	191,504	1,305,730	558,173	342,800	1,261,926	1,458,392
2005	195,856	1,650,255	553,455	366,537	1,267,297	1,659,105
2006	189,070	2,090,115	597,882	411,689	1,318,720	1,890,491
2007	226,824	2,317,134	651,216	468,347	1,378,874	2,145,973
2008	219,138	2,265,346	655,530	466,630	1,451,262	2,338,775
2009	229,417	2,327,534	732,432	449,753	1,440,725	2,542,960

This data is for figure 6 on page13: Chart shows the share of world fisheries production destined to exports

Years are on the horizontal axis, million metric tons of aquaculture is on the vertical axis.

	Production	Export
1976	69	17.3
1977	68	17.7
1978	70.2	18.7
1979	70.8	20.6
1980	71.9	21.1
1981	74.7	20.4
1982	76.8	22.7
1983	77.3	21.7
1984	83.6	23.9
1985	86.3	27.4
1986	92.9	29.3
1987	94.9	30.1
1988	99.5	31.3
1989	100.6	33.8
1990	97.7	32.3

1991	97.3	32.8
1992	100.6	34
1993	104.3	38.5
1994	112.9	45.2
1995	116.7	43.7
1996	120.4	43.3
1997	122.8	45.2
1998	118.1	38.3
1999	127	42.8
2000	131.1	48.6
2001	131	49.3
2002	133.6	48
2003	133.2	47.7
2004	140.5	52.1
2005	142.7	55.9
2006	143.6	53.5

This data is for figure 7 on page 14: Chart shows the world fish trade in value of exports

Years are on the horizontal axis, value of aquaculture exports in billion US dollars is on the vertical axis.

	Developed	Developing
1976	5,036,248	2,943,676
1977	5,963,827	3,695,889
1978	7,250,999	4,680,415
1979	8,595,993	5,744,458
1980	9,368,233	6,148,914
1981	9,421,247	6,588,750
1982	8,925,249	6,596,991
1983	9,196,267	6,664,301
1984	9,126,619	6,964,757
1985	9,747,245	7,382,444
1986	12,657,776	10,079,659
1987	15,410,922	12,387,400
1988	17,349,376	13,938,507
1989	17,236,566	14,464,198
1990	20,323,353	15,501,298
1991	21,372,180	17,222,013
1992	22,028,565	18,073,241

1993	21,413,481	19,820,792
1994	23,938,463	23,764,236
1995	25,811,780	26,247,528
1996	27,017,826	26,051,981
1997	26,170,477	27,459,775
1998	26,322,616	25,065,202
1999	27,798,462	25,277,005
2000	27,468,664	27,935,807
2001	28,031,866	28,364,260
2002	29,787,458	28,712,193
2003	34,600,000	33,173,000
2004	36,800,000	34,800,000
2005	40,200,000	38,200,000
2006	43,400,000	42,500,000
2007	47,800,000	45,700,000
2008	50,700,000	51,500,000
2009	45,600,000	48,900,000

This data is for figure 8 on page16: Chart shows the hourly compensation costs of manufacturing employees

Countries are on the horizontal axis, index values are on the vertical axis. $29.98 = 100, 2006

Country	Index of hourly compensation costs
United States	100
China	3
Philippines	5
Mexico	13
East Asia (excluding Japan)	40
Japan	80
Euro Area	122

This data is for figure 9 on page 28: Chart showing the unit process flow diagram of an RAS system used to rear tilapia in a RAS

A simplified unit process diagram is shown that is used to rear tilapia. Water leaves the biological filter (CycloBio) tank, is stripped of CO2 and then a 'Low Head Oxy-generator' adds oxygen to the water. The water is then moved into the fish production tanks. From the fish production tanks, 10% of the water moves into the solids settling chamber and 90% of the water flows from the tank. Once the solids are removed the water is pumped back into the CycloBio chamber and the process repeats.

This data is for figure 10 on page 42: Diagram shows the processes for determining if a disease is insurable or not

Question 1: Are the probabilities of getting this disease conditioned on management?
If yes, the disease is not insurable.
If no, go to question 2.
Question 2: Are measures available to prevent and mitigate the severity of the outbreak?
If yes, the disease is not insurable.
If no, go to question 3.
Question 3: Can one clearly determine that this disease alone primarily causes the loss?
If yes, go to question 4.
If no, go to question 5.
Question 4: Does this disease cause acute losses?
Go to question 6.
Question 5: Are the other disease associated with losses from this disease insurable?
If yes, go to question 6.
If no, the disease is not insurable.
Question 6: Can a loss (i.e. dead fish) from this disease be quantified?
If yes, the disease is potentially insurable.
If no, the disease is not insurable.

This data is for figure 11 on page 52: Chart shows the predicted number of fish per pound throughout the production period

Days are on the horizontal axis, number of fish per pound is on the vertical axis.

Days	Fish per pound
15	38.86
30	22.25
45	13.91
60	9.27
75	6.48
90	4.71
105	3.53
120	2.71
135	2.13
150	1.7
165	1.38
180	1.14
195	0.95
210	0.8

This data is for figure 12 on page 99: Chart showing trout losses by type over the years 2000 to 2010.

Years are on the horizontal axis, the number of fish is on the vertical axis.

	Disease	Predators	Other	Drought	Chemicals	Flood	Theft	Total
2000	25,022	2,707	423	978	5	184	303	29,622
2001	33,135	5,973	3,994	863	83	168	392	44,608
2002	29,134	2,716	1,465	1,443	16	51	134	34,968
2003	23,713	3,610	367	578	4	256	316	28,844
2004	15,942	2,167	718	110	9	2,646	86	21,892
2005	16,359	2,674	6,618	6,188	4	256	22	32,124
2006	27,885	1,344	667	564	30	256	104	30,850
2007	28,108	2,790	466	1,425	24	96	30	32,879
2008	22,760	1,181	706	1,428	23	164	26	26,288
2009	17,564	1,118	363	282	2	192	36	19,557
2010	14,648	1,571	968	940	116	85	74	18,412