HUBBS-SEAWORLD RESEARCH INSTITUTE
OFFSHORE AQUACULTURE DEMONSTRATION PROJECT

EXECUTIVE SUMMARY

Hubbs-SeaWorld Research Institute (HSWRI) will establish the first commercial-scale, offshore aquaculture demonstration project in federal waters of the United States. In addition to being commercially viable, the project is designed to monitor and evaluate concerns related to the environmental sustainability of offshore aquaculture.

HSWRI is a 501(C)(3), non-profit, public trust research foundation established in 1963. Over the past four decades, HSWRI has provided global leadership in marine conservation, including research in marine aquaculture. HSWRI operates two marine fish hatcheries in southern California and several cage sites in California and Baja California, Mexico. HSWRI has expertise in fish nutrition, reproduction, health, genetics, and physiology, as well as site selection and permitting, systems engineering, and environmental monitoring.

This offshore aquaculture demonstration project is being driven by the global demand for healthful seafood and a lack of domestic production. Traditional harvest fisheries are fully exploited and cannot meet the increasing demand for seafood. The demand is fueled by an increasing world population and the growing per capita consumption of seafood. In the U.S., more than 80% of seafood is imported and half of that supply comes from aquaculture operations. This represents a $9 billion contribution to the U.S. trade deficit, which is second only to oil.

The proposed project will produce 3,000 metric tons (MT) of striped bass each year in surface cages that are located five miles from the southern California shoreline. Striped bass is an established species in local waters and cultured juveniles are readily available from commercial suppliers. The site will also be permitted for other local species such as yellowtail jack, California halibut, and white seabass, which will be interchangeable with striped bass once juveniles are readily available. Production will be phased in 1,000 MT increments beginning with 1,000 MT in the first year in order to achieve operational efficiency and ensure environmental compatibility. In addition, HSWRI plans to use this facility and capability to develop related aquaculture activities around the farm, such as mussel and seaweed culture, that will seek to integrate production from both operational and environmental standpoints. Traditional surface cages, nets, and mooring systems will be used for this project because of their demonstrated compatibility with mild ocean conditions characteristic of the Southern California Bight.

If successful, this project will serve as a model for the development of offshore aquaculture in California and the United States. It will create jobs, including new jobs for displaced commercial fishermen, and it will ensure that the existing infrastructure for fish processing and distribution has a viable future. The consumer will benefit from a year-round supply of high quality seafood that is safe and healthful. The environment will benefit as a high quality seafood source is produced significantly more efficiently than capture fisheries or land-based practices can achieve. In addition, the supplemental supply of high quality farmed fish will take pressure off wild fisheries.

PROJECT NEED

A growing demand for seafood is being fueled by growing human populations and increasing awareness of its health benefits. Capture fisheries are at or near their maximum production with many fisheries becoming depleted. Increased worldwide demand for seafood can only be met by increased production from aquaculture (Figure 1). This is recognized in many parts of the world; aquaculture production has increased in Japan, Europe and Asia in recent years. By comparison, the United States has delayed development of marine aquaculture, resulting in a steady increase in seafood imports, which now exceed $11 billion annually and represent 80% of total seafood consumption. Yet, despite what appear to be inevitable future pressures on seafood supply, global expansion of aquaculture in freshwater and nearshore marine waters is now limited by competition with other users, poor water quality in some areas, and environmental activism. In the U.S. it is further hampered by a poorly delineated permitting process and lack of experience on the part of regulatory agencies. This project hopes to resolve these limitations.

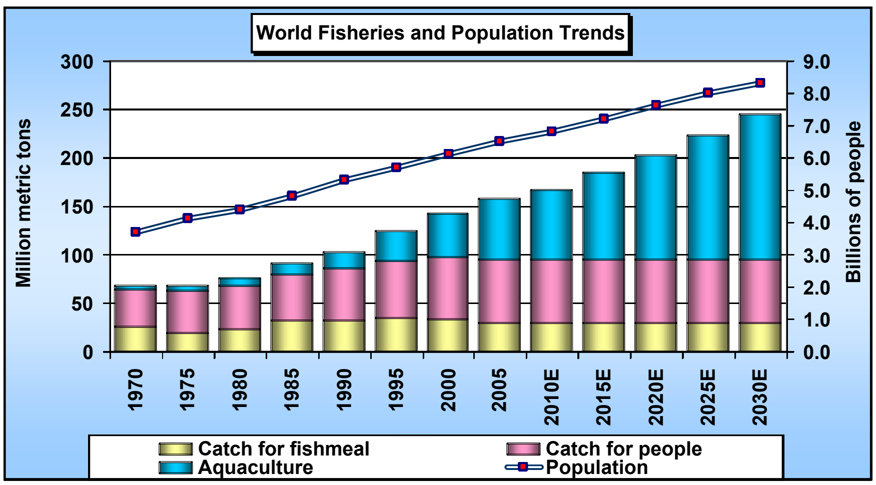


Figure 1. Trends in world fisheries, aquaculture and human population

(Courtesy Chu & Anderson, NOAA pers. comm)

This has prompted efforts in the U.S to try to develop aquaculture away from the coastline, where water quality is better and conflicts are less. In the U.S. there is a drive to develop aquaculture in federal waters 3 to 200 miles from the coastline, which is now before U.S. Congress as the Offshore Marine Aquaculture Act of 2007. This effort is in recognition of the need to develop offshore aquaculture and of technological advances in the industry that now make this possible. This acknowledged need combined with the technology now available provides the basis for this demonstration project.

PROJECT RESEARCH TEAM

Hubbs-SeaWorld Research Institute (HSWRI) is a 501(C)(3), non-profit research foundation established in 1963. The Institute's mission is to "return to the sea some measure of the benefits derived from it." In the past four decades, HSWRI has provided global leadership in marine conservation including research in marine aquaculture, which has been a core program for more than 30 years.

HSWRI is a national leader in the hatchery production of marine finfish and operates a production-scale hatchery in Carlsbad, California capable of rearing up to three million fingerling white seabass per year (Figure 2). This is a cooperative program with the California Department of Fish and Game, with all seabass produced being released into the ocean to replenish wild stocks. Each fish has to meet the highest standards of quality in terms of appearance, health and genetic diversity. HSWRI also operates a research-scale hatchery in San Diego for rearing other commercially valuable species – both for replenishment and marine farming. Both these hatchery facilities use state-of-the-art, energy efficient life support systems and have been built and are operated to comply with California's rigorous permit requirements.

Figure 2. HSWRI hatchery in Carlsbad, CA for rearing white seabass.

HSWRI has also worked with cage systems for growout of juvenile fish since 1991. In 1997, it received a federal grant to expand its work by establishing a four-cage system (Figure 3) off Santa Catalina Island where white seabass were grown to a weight of 1kg (2.2lbs) before being harvested and test-marketed. The results were encouraging and significant market potential was recognized. HSWRI also operates two other cage systems and coordinates the activities of twelve other volunteer-based growout facilities in Southern California for replenishment of white seabass stocks.

Figure 3. HSWRI Catalina Island Cage Facility

In 2007 HSWRI began an offshore aquaculture project in collaboration with Mexico's largest bluefin tuna farm, Maricultura del Norte, in Ensenada, Baja California, Mexico, approximately 60 miles south of San Diego (Figure 4). This project is evaluating two species of marine fish – yellowtail jack and striped bass, as well as two different cage designs.

Figure 4. HSWRI and Maricultura del Norte joint project to grow striped bass and California yellowtail.

HSWRI understands the need for increased production from ocean farms to meet worldwide demand for seafood and to alleviate fishing pressure on wild populations. Consistent with its charter, HSWRI intends to conduct research and development to fully test the viability of commercial-scale aquaculture in the offshore environment.

This will begin with a commercial fish farming project that builds on the last 30 years of development and research on the production of fish in net pens. This promises immediate commercial viability, which will make it possible to attract the investment necessary to develop the farm and supporting infrastructure in Southern California. Once this is in place, however, HSWRI plans to use this facility and capability to develop related aquaculture activities around the farm, such as mussel and seaweed culture, that will seek to integrate production from both operational and environmental standpoints.

HSWRI has experience in several other branches of aquaculture research and development that will be valuable in the execution of this demonstration project (see Appendix I). In summary, HSWRI has established or developed expertise in the following areas:

1. Hatchery methods including broodstock management, larval rearing and live feeds production
2. Offshore cage farming methods including transportation of fish and operation of both surface and submersible cages
3. Fish nutrition
4. Fish health
5. Fish physiology
6. Fish reproduction
7. Fish marking, tagging and tracking
8. Genetics
9. Site selection and permitting
10. Environmental monitoring
11. Systems design and engineering
12. Developed methods for raising several other marine finfish as part of programs to examine their potential for wild fishery replenishment or commercial farming

PROJECT SCOPE

The proposed demonstration project will apply a scaled or phased approach to develop an offshore fish farm in the Exclusive Economic Zone (EEZ) offshore of southern California to produce a maximum of 3,000 metric tons (MT) per year of striped bass and other species to be sold in the United States. The project is phased over five years with a steady state of production from five years and beyond to allow for the necessary permits to be secured. A clearly defined expansion of farm capacity would be allowed after an appropriate environmental evaluation is completed. Initially the farm will be stocked to produce up to 1,000 MT of product at peak biomass. The farm will operate in this capacity while all aspects of production will be closely monitored and documented. Demonstrating the efficacy of the venture at 1,000 MT will ensure that all the proper safeguards are in place before scaling up further. The driving force and timeliness of the plan stem from several key business considerations:

- U.S. demand for seafood products from aquaculture is growing rapidly as demand cannot be met from either domestic harvests or existing farms.
- All species proposed for this venture are regionally important species to California with well established markets.
- HSWRI is a national leader in the technology for producing marine finfish – both at sea and on land.
- Equipment is now available that makes farming possible in unsheltered waters off the southern California coast.
- HSWRI's reputation as a leading marine research institution and steward of the marine environment will ensure that the venture is managed properly.
- HSWRI has an outstanding team of aquaculture specialists and advisers who are well qualified to implement the project.
- The waters off southern California and Mexico offer possibly the best marine growing conditions for striped bass and other temperate water marine fish, as well as mussels and seaweeds.

Inherent in the project design is the ability to assist government regulatory agencies and the lay community in developing national aquaculture guidelines through extensive, proactive monitoring and reporting programs. Increased initiatives at the national level, increased demand for seafood and commercial enterprise development are all driving forces that will help to expand aquaculture into the offshore environment. The results of this demonstration project will be directly applicable and serve as a model for the responsible development of sustainable offshore aquaculture in the U.S.

PROJECT APPROACH

The proposed demonstration project will grow striped bass, and other local species such as yellowtail jack, California halibut, and white seabass in open ocean cages five miles from shore. The resulting products will be available in the freshest form possible, on-demand, and with an assurance of quality unavailable from a harvest fishery or foreign aquaculture. Striped bass has been chosen as the initial species as juveniles are readily available from a number of suppliers including farms in California. Hatchery technologies have been developed for all the other species and as larger numbers of juveniles become available, these species will be integrated into the project. Once the project is operational, future considerations could include use of the facility and capability to develop related aquaculture activities around the farm, such as mussel and seaweed culture, that will seek to integrate production from both operational and environmental standpoints.

The project will initially employ traditional gravity type cages, nets, and mooring systems. These types of cages are proven technology in exposed environments, used globally and are commercially available. However, as technologies for offshore aquaculture continue to advance, the project will be flexible enough to incorporate any new systems or other technologies that improve production efficiencies in the offshore environment.

Site Description

The proposed project location is approximately five miles west of Mission Bay in San Diego, CA (see Figures 5,6, and 7), at Latitude 32º47.000'N, Longitude 117º22.000'W. A variety of criteria were used in selecting the site, including depth, currents, temperature, bottom sediment type and habitat, proximity to shore based infrastructure, and avoidance of areas that would result in any potential user conflicts (other commercial and recreational activities). HSWRI deployed an acoustic Doppler current meter at the site for over 90 consecutive days in 2008 to provide further insight on water column currents, collected and analyzed sediment samples, and used a bottom and depth sounder across the entire site location to ensure that there was no hard bottom or other habitat in the proposed area. This and other site and species information was also used by a third party consultant, Science Systems Applications for integration into their proprietary modeling program, AquaModel to simulate water and sediment quality effects of the proposed demonstration project (see corresponding report, "AquaModel Simulation of Water and Sediment Effects of Fish Mariculture at the Proposed Hubbs-SeaWorld Research Institute Offshore Aquaculture Demonstration Project").

The following is a brief summary of environmental data collected specific to the site:

- Maximum Wind Speed (m/sec): 23
- Prevailing Wind Direction (from): 261^{o} T
- Significant Wave Height (m): 5.0
- Water Depth (m): Avg 91, ranging from about 80 to 140
- Maximum Tidal Variation (m): 2.73
- Current Velocity (m/sec): Max 0.6 m/s average <0.2 m/s
- Prevailing Direction of Current: The average prevailing direction ranges from 169^{o} to 259^{o} T. The current measurements we have made in this location show a cyclical pattern of heading south (176^{o} T averaged direction throughout the water column) and then changing to a more westerly direction (250^{o} T averaged direction throughout the water column).
- Bottom Conditions: The seafloor in this area is generally flat with a gentle slope heading to the west 280^{o}T. The sediments are relatively coarse (21% silt and clay, the remainder is sand or gravel).

In summary, the proposed location may be characterized as exposed, deepwater coastal shelf remote from sensitive habitats such as nearshore kelp beds, rocky, hard bottom substrates, seal or seal lion haul outs, or other aquatic resource areas. The type of bottom sediments reflect the relatively strong surface and bottom currents. The area is also remote from islands, seamounts, hard bottom habitat, and any other abrupt changes in bottom bathymetry, as well as away from usual navigational lanes.

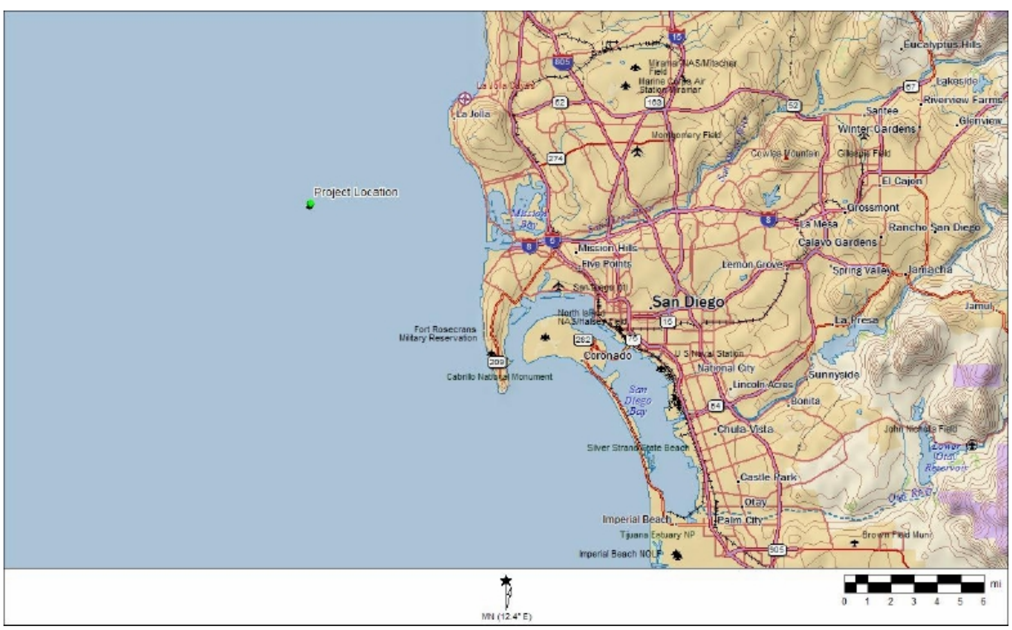


Figure 5. Map of project location.

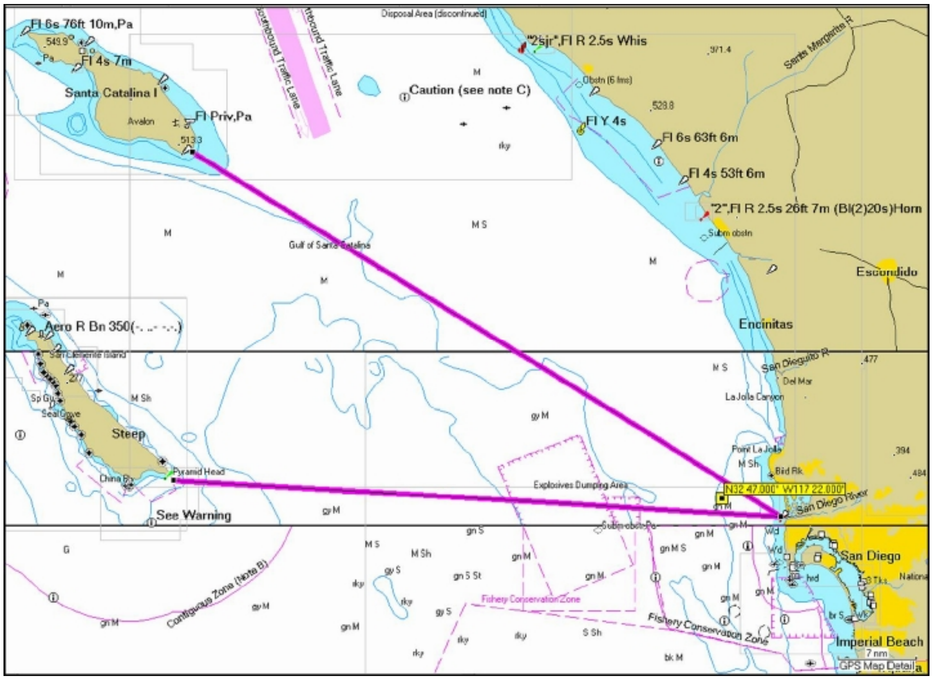


Figure 6. Vicinity map showing site location (yellow square with black center) and main navigational paths to San Clemente Island (south) and Santa Catalina Island (north).

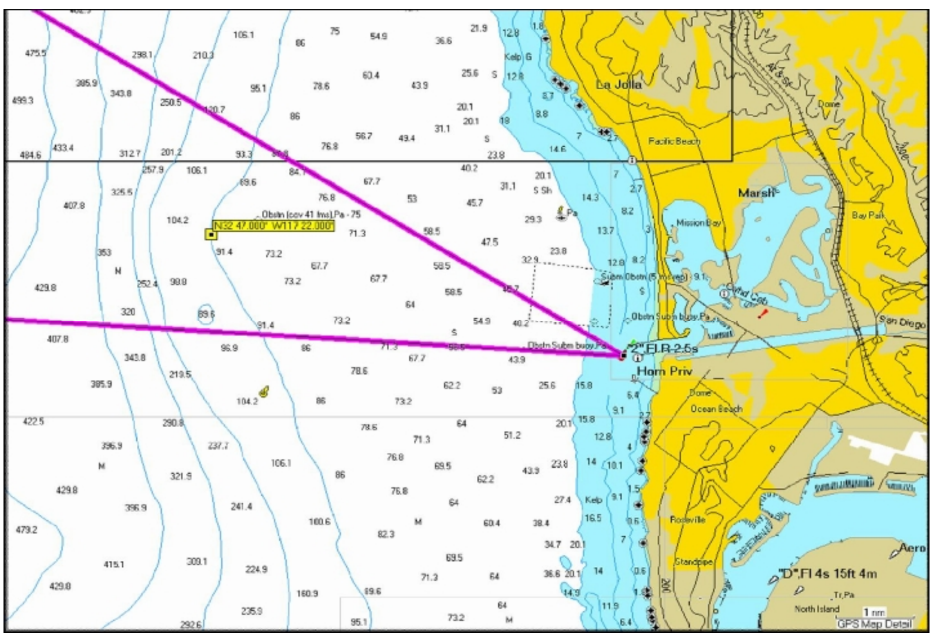


Figure 7. Close up of vicinity map with depths in meters.

Culture Systems

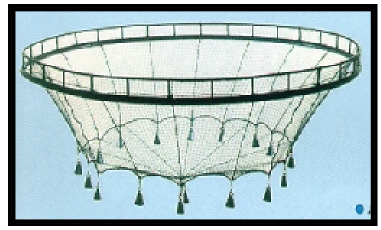


Figure 8. Illustration and photograph of a traditional gravity cage design.

Gravity cages. A gravity cage consists of a single or double ring collar made of high-density polyethylene (HDPE) pipe (Figure 8). The pipe is filled with closed cell flotation with a net suspended from the collar. HDPE type or steel type stanchions are installed at intervals around the ring to reinforce the pipe structures as well as support net systems, handrails and walkways. All cage equipment, including navigational aids are supported directly by the flotation structure. Gravity cages come in a wide range of sizes and associated volumes. This project will initially use eight gravity cages of up to 9,000 m^3 each and will incrementally be scaled to a maximum use of 24 gravity cages, according to a carefully monitored and phased approach described in the previous section.

Cage netting. Proposed nets and associated mesh sizes are standard in the industry, both in the U.S and throughout the world. Each gravity cage will have two types of nets; a primary net, which serves as the main containment net for the fish, and an anti-predator net, which acts as a barrier to the primary net and keeps predators at a safe distance (1 m) from the fish being cultured. All nets on gravity cages are weighted from the bottom. This keeps the nets taut so the desired culture volume is maintained and so animals do not become entangled. Primary containment nets will be suspended to a maximum depth of 18 m, with mesh sizes ranging from of 1.9 to 5.7 cm stretch, depending on size of fish being cultured. Predator nets will be 8 cm stretch mesh and extend below the primary nets by a minimum of 1 m.

Mooring systems. A mooring grid capable of accommodating up to 24 cages will be installed before installation of the first 8 cages as a one-time purchase in order to optimize efficiency and cost. The primary portion of the mooring grid is typically submerged between 3 to 5 m below the surface and consists of appropriately sized anchors, chain, ropes, and assorted flotation structures. The grid and assembly is designed and installed using site-specific criteria such as depth, current, and bottom type. The final installation of the mooring grid will be perpendicular to the prevailing current direction in order to maximize flow of fresh seawater through the entire system. The cage equipment manufacturers as well as experienced maritime contractors will specify all mooring system configurations. Cage moorings will be inspected at regular intervals and after storm events. Plan and elevation view drawings of mooring configurations, as well as a site map, can be found in Appendix II.

Culture Species

All of the species proposed for this venture are regionally important species to California with well established markets. Striped bass has been chosen as the initial species as juveniles are readily available from several California suppliers. Hatchery technologies have been developed for all the other species, primarily at HSWRI facilities and as larger numbers of juveniles become available, these species will be integrated into the venture.

<u>Striped Bass (Morone saxatilis)</u>

Striped bass will be stocked into the cage systems at an average size of 5-25 grams. Market size for this species is between 1-2 kg. Their production cycle can range from 24–36 months depending on water temperature. More detailed information on striped bass can be found in Appendix V.

<u>White Seabass (Atractoscion nobilis)</u>

This species has been evaluated as a primary candidate for stock repleinishment since 1983. Four groups of captive broodstock are held at the HSWRI hatchery in Carlsbad under controlled conditions to provide eggs year-round. HSWRI has conducted release, growout and marketing trials on this species. Similar to striped bass, market size for this species is between 1-2 kg. Their production cycle can range from 18–24 months depending on water temperature.

<u>California Halibut (Paralichthys californicus)</u>

This species has been evaluated as a secondary candidate for stock replenishment at a modest scale since 1983. Captive broodstock are held at HSWRI's research facility in San Diego under ambient conditions and provide eggs year-round. HSWRI has conducted release, growout and marketing trials on this species. Preferred market sizes range from 1-4 kg. Their production cycle can be as much as 36 months, depending on water temperature.

<u>California Yellowtail (Seriola lalandi)</u>

A transitory, seasonally abundant species in southern California, yellowtail are valued as both a game and food fish. They are highly prized in the sushi markets and sold as hamachi. Captive broodstock are held at HSWRI's research facility in San Diego under ambient conditions and provide eggs in the spring and summer. HSWRI has conducted growout and marketing trials on this species. Preferred market size is 4 kg. Their production cycle can range from 24-36 months, depending on water temperature.

Daily Operations

Fish will be fed several times per day with a pellet feed that is customized for each species under culture. The customization is designed to optimize the health and growth of the fish with the following critical considerations: 1) the nutritional requirements of the fish, 2) the conversion efficiency [food converted to fish flesh] to minimize the waste of feed, and 3) the cost of ingredients to maximize profits. The size of feed is increased incrementally as the fish grow to maximize their feeding efficiency. Use of alternative sources of protein to replace fish meal in the diets is a priority, and finishing diets may be used to adjust the flesh quality to match consumer preferences several months prior to marketing. Automatic feed blowers and feeders are used to dispense the feed to the fish. Observations of feeding behavior (direct from surface and underwater video) are used to continuously adjust the amount of feed dispensed each day so that feed is not wasted. Divers will also perform daily cage and system inspections. Once per month throughout the production cycle, a sample of fish from each cage will be weighed and measured to track growth performance (biomass, feed conversion ratio, etc) and to perform routine fish health inspections.

Harvesting, Handling, and Packaging

Fish produced by the project will be harvested fresh weekly. Fish will not be processed beyond whole or gilled and gutted product within project infrastructure, but delivered by boat to shore and transferred to fish traders, brokers, wholesalers, or other pre-determined fish distribution outlets . The fish will be transported in insulated fish totes filled with a slurry of ice and brine. HSWRI will work with the State Department of Health Services (SDHS), the United States Department of Agriculture's (USDA), Food Safety and Inspection Service (FSIS) to develop an appropriate Hazard Analysis and Critical Control Point (HACCP) plan to monitor all product handling and maintain the highest quality assurance standards.

Fish will be packaged by registered fish traders, brokers, wholesalers, or other pre-determined fish distribution outlets. Product packaging typically consists of insulation-lined, appropriately labeled cardboard boxes, accommodating various amounts of fish per box, and kept chilled with fresh flaked ice, or gel ice packs, as determined by the purchaser.

Feed Quality and Supply

Feed is purchased only from reputable manufacturers that have rigorous quality control standards. Several such manufacturers exist in the United States and Canada. HSWRI will also implement protocols to ensure food quality such as proper storage, frequent turn-over, and routine inspection. All feed shipments will be accompanied by a guaranteed chemical analysis certificate, and if purchased from Canada, an export certificate from the Canadian Food Inspection Service, and a United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) Veterinary import permit. Additionally, HSWRI is involved in many research studies evaluating alternative sources of protein to substitute for the fishmeal portions of fish feeds. The results of these studies will be integrated into the program as commercially available feed formulations are developed.

High quality fish feed is readily available from manufacturers in the United States and Canada. Orders are placed far enough in advance to ensure an uninterrupted supply to support farm operations. HSWRI routinely sources high quality feed from the following manufacturers:

Skretting, Vancouver, Canada
Bio-Oregon, Inc., Washington, USA
Nelson's Silver Cup, Utah, USA

Risk Management

A detailed list of farm specific risks and associated management strategies is described in Appendix IV.

PROJECT BENEFITS

The potential benefits of this offshore aquaculture demonstration project are numerous and substantial. The sectors that will most directly benefit from this project will be the aquaculture and seafood industries. The results of this project will be readily transferable to commercial aquaculture enterprises and will include appropriate culture, marketing and evaluation methodologies. Consumers and wholesalers will benefit from an increased supply of commercially valuable species from local California waters. An increase in cultured product could potentially help reduce the fisheries trade deficit by reducing imports and increasing exports of seafood products.

The participation of government agencies, universities, fisheries managers and the scientific community will aid in the technology transfer to commercial culturists by providing direct experience from a practical, large-scale application. A project of this kind will also promote an understanding of aquaculture by the public as well as by permitting and resource agencies. The facility will be available for tours by interested parties and all progress and accomplishments will be disseminated at national and international meetings related to aquaculture and fisheries.

The transferable knowledge developed from this project will help ensure that the U.S. aquaculture industry increases its profitability and competitiveness in the global marketplace. Additionally, developing and promoting offshore aquaculture operations will help create jobs and economic growth in this area. Finally, it is hoped that this project will serve as a model for the responsible utilization of renewable resources and sustainable development of aquaculture in the U.S. Exclusive Economic Zone.

APPENDIX I. HSWRI QUALITY ASSURANCE PROGRAMS AND RELATED EXPERIENCE

HSWRI Quality Assurance Programs and Related Experience

Because of its long history of aquaculture research, HSWRI is well aware of the primary concerns related to aquaculture development. Recognizing that successful aquaculture programs require a multidisciplinary approach, HSWRI has developed its own supporting branches of research and operational support in areas related to hatchery and cage production, fish nutrition, fish health, fish physiology, fish reproduction, fish tagging and tracking, genetics, site selection and permitting, environmental monitoring, and systems engineering. In addition, HSWRI scientists utilize an extensive, ever-growing network of outside collaborators to fulfill their research mission and also to offer their expertise. Graduate students from local and foreign universities also play an integral role in this process.

Hatchery Production

HSWRI is a national leader in the hatchery production of marine finfish and operates a commercial-scale hatchery in Carlsbad, California capable of rearing up to three million fingerling white seabass per year. This is a cooperative program with the California Department of Fish and Game, with all seabass produced being released into the ocean to replenish wild stocks. Each fish has to meet the highest standards of quality in terms of appearance, health and genetic diversity. HSWRI also operates a research-scale hatchery in San Diego for rearing other commercially valuable species – both for replenishment and marine farming. Both these hatchery facilities use state-of-the-art, energy efficient life support systems and have been built and are operated to comply with California's rigorous permit requirements.

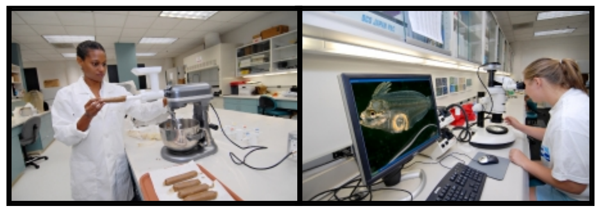
Offshore Cage Production

HSWRI has also worked with cage systems for growout of juvenile fish since 1991. Fish are transported in purpose built live fish haul tanks from the hatcheries to commercial fishing boats with appropriate live haul capacities. The fish are then delivered to cage systems. In 1997, HSWRI received a federal grant to expand its work by establishing a four-cage system off Santa Catalina Island where white seabass were grown to a weight of 1kg (2.2lbs) before being harvested and test-marketed. The results were encouraging and significant market potential was recognized. HSWRI also operates two other cage systems and coordinates the activities of twelve other volunteer-based growout facilities in Southern California for replenishment of white seabass stocks.

In 2007 using NOAA funding HSWRI initiated an offshore aquaculture project in collaboration with Mexico's largest bluefin tuna farm, Maricultura del Norte, in Ensenada, Baja California, Mexico, which is approximately 60 miles south of San Diego. This project is evaluating two species of marine fish – yellowtail jack and striped bass, as well as two different cage designs.

Fish Nutrition

Because many of the species HSWRI is culturing are new for the industry, formulated feeds have not been customized for these species. HSWRI has developed its own nutrition program and is also working with nutritionists from California, Mexico and Japan to develop the needed custom diets, including those with reduced a proportion of fish meal as a raw ingredient.



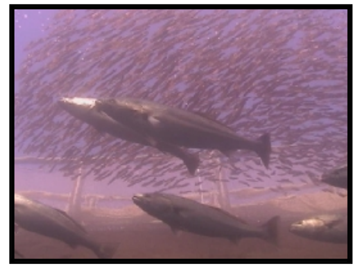
Fish Health

Scientific understanding of marine pathogens is very limited. While some organisms are relatively easy to identify (e.g. parasites), others (e.g. viruses) are not. HSWRI scientists have teamed up with a network of local and international fish health professionals to gain access to their expertise and the most sophisticated detection and identification tools available. A description of HSWRI's Fish Health Management Program is detailed in Appendix III. Therapeutants for use in aquaculture are extremely limited. Many of those that do exist are further restricted to certain culture species and pathogens. HSWRI is actively involved with government Investigational New Animal Drug (INAD) programs, industry (e.g. vaccine development), and university research (efficacy trials) to overcome these limitations.

Fish Physiology

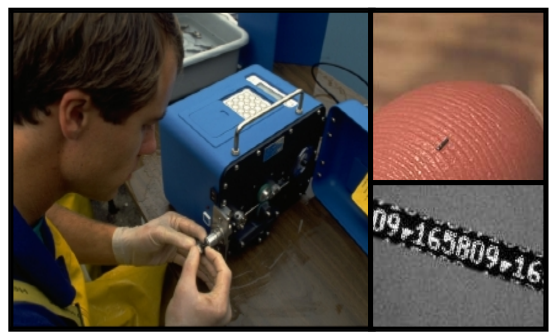
In order to enhance culture success, it is critical to understand and define the optimal rearing conditions that promote good growth and health in the fish under culture. These conditions are best measured by extensive laboratory trials testing physiological thresholds to variables such as water temperature. HSWRI has established an in-house physiology program and a broadening network of external collaborators.

Fish Reproduction



HSWRI maintains viable fish breeding populations of several regionally important species, including white seabass, yellowtail jack, California halibut, cabezon, lingcod, and several rockfish species. Conditions within each breeding population are carefully controlled to provide the optimum environment for each species.

Fish Marking, Tagging, and Tracking



HSWRI has evaluated a variety of fish tags and tagging techniques, including external, visible implantable, coded wire, and acoustic tags. As part of the white seabass replenishment program, each fish is tagged in the cheek muscle with a coded wire tag, which is unique to each lot of fish released. HSWRI also maintains a post release assessment program which incorporates sampling of sub-legal sized fish, cooperation between recreational and commercial fishermen, and the use of acoustic tags and tracking techniques to gain a better understanding of released fish and their contribution to the wild population.

Genetics

Stock replenishment programs require a substantitive understanding of the genetic diversity of the population being supplemented, as well as that of the cultured fish being stocked. Breeding programs for traditional farming will look toward genetic selection to retain and improve positive attributes for culture such as disease resistance and growth enhancement. HSWRI is currently developing its own genetic research program in cooperation with NOAA Fisheries.

Site Selection and Permitting

Through its extensive experience in operating land-based and coastal facilities, HSWRI has developed an important core competency in acquiring the myriad of permits necessary to conduct aquaculture in the coastal zone, as well as in federal waters. HSWRI also has the tools and expertise to identify appropriate offshore sites for aquaculture.

Environmental Monitoring

HSWRI has established an extensive environmental monitoring program for its coastal cages in California and in Mexico. The program has been developed in consultation with experts from around the country and is patterned after the methods used in Washington state and British Columbia to monitor salmon farming operations toward developing best management practices to minimize impacts to the environment. The monitoring program in California has been approved by various coastal agencies in California. HSWRI also monitors effluent from its land-based facilities as a requirement of the Regional Water Quality Control Board.

Systems Engineering

HSWRI has developed an in-house capability for designing efficient and functional flow-through and recirculating life support systems for fish. These systems are critical for maintaining brood fish and rearing large numbers of sensitive larval and juvenile stages of marine finfish that can ultimately be stocked into cages.

Other Species

HSWRI is active in evaluating, either directly or through collaborations several other commercially valuable species that can be considered for commercial culture, stock replenishment or other research and development purposes. They include but are not limited to: Tunas, Thunnus spp., sablefish, Anoplopoma fimbria, spot prawn, Pandalus platyceros, mussels, Mytilus edulus, red sea urchin, Stongylocentrotus purpuratus, California sheephead, Semicossyphus pulcher, boccacio and other rockfish, Sebastes spp., lingcod, Ophiodon elongatus, abalone, Haliotus sp., giant keyhole limpet, Megathura crenulata and the California brown sea hare, Aplysia californica.

APPENDIX II. SITE MAP AND MOORING CONFIGURATION FOR HSWRI OFFSHORE AQUACULTURE DEMONSTRATION PROJECT

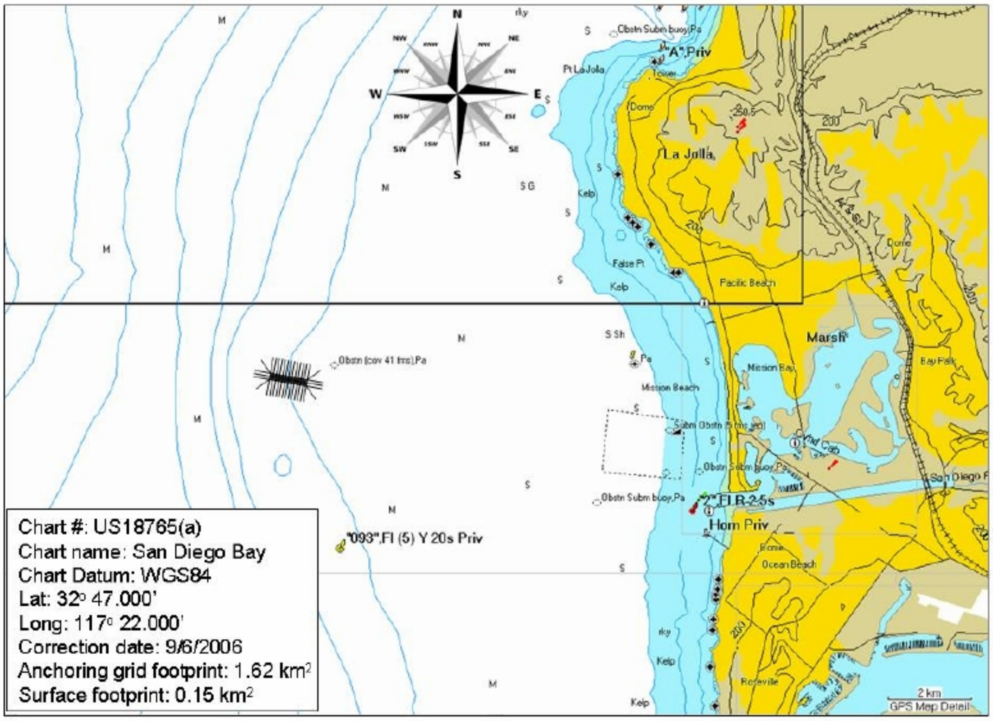


Figure II.1. Project Location: Site Detail with Cage Grid Overlay

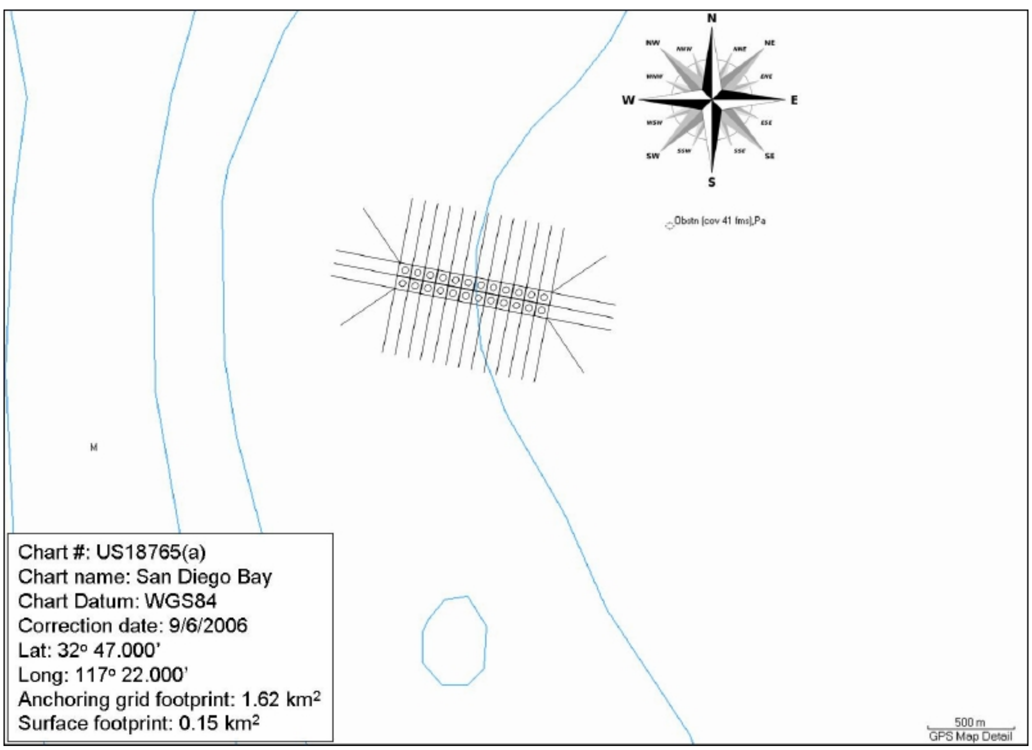
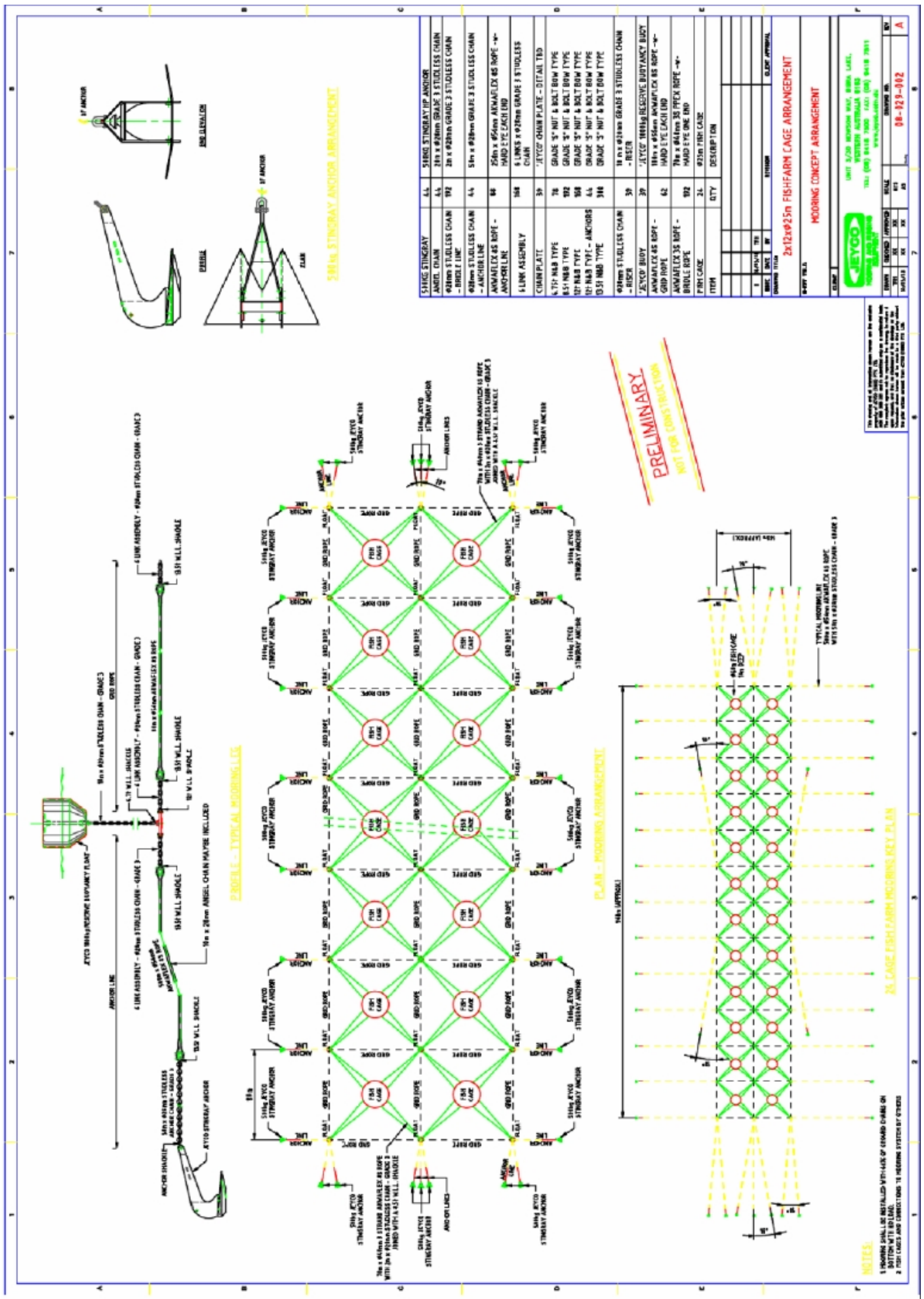


Figure II.2. Close up of Cage Grid Overlay

Figure II.3. Plan and Elevation View Drawings of Cage Grid and Mooring System Components



APPENDIX III. FISH HEALTH MANAGEMENT

Disease Prevention

HSWRI's approach to aquaculture health management begins with disease prevention. Disease prevention is only possible when the culture requirements of the animal are well understood and accommodated to every extent possible, or when best management practices are employed for new species. Examples of culture requirements and best management practices are discussed below. It is important to recognize that factors affecting fish health status are complex. Fish health status cannot be determined solely by the presence or absence of infectious agents (i.e. pathogens). More often than not, infectious diseases that lead to death of the host are opportunistic and secondary to some other stressor (e.g. poor water quality, nutrition, husbandry, immunity) that is the primary cause of mortality. Health management efforts will not be successful until the primary cause is identified and corrected.

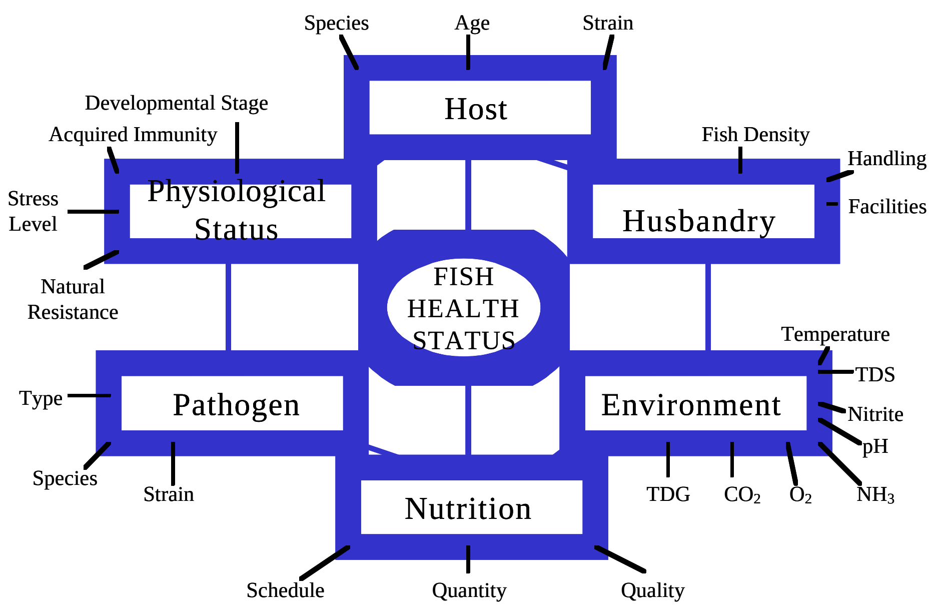


Figure III.1. Factors affecting farmed fish health (adapted from Plumb, 1999)

Stock origin and biosecurity

All fish grown are endemic to California. Biosecurity refers to measures taken to ensure that the fish in culture are secure from infectious agents. Potential vectors for disease are identified and mitigated to every extent possible. When new fish are brought into the hatchery or cages, they are inspected by a certified health professional, quarantined, and treated for any diseases as necessary. Water is sterilized using ultraviolet light in recirculating systems, and the volume of new water added is relatively small. Employing these procedures minimizes the risk of introducing diseases from other culture facilities or wild fish. Similar safeguards are employed with regard to feeds, where only fresh, high quality fish food is used. Good hygiene practices are employed with regard to culture systems, equipment and personnel. All nets, siphon hoses, feed containers, and any other equipment used for operations are cleaned and disinfected after use. Each rearing system has its own cleaning and feeding supplies. Mortalities are removed and disposed of immediately, so they do not provide an additional vector for disease.

Environmental conditions

Environmental requirements vary among species but can often be inferred based on the lifestyle of the species in the wild. Water quality is extremely important for aquatic organisms; therefore, the quality of the water must be maintained at high standards to avoid stress and disease. Many common diseases occur because of poor water quality. Good water quality is characterized by high dissolved oxygen, and low levels of waste (ammonia, nitrite, and suspended solids). These parameters are measured daily and compensated for by properly designed systems and sound husbandry practices. Adequate water flow, particulate and biological filtration, supplemental aeration, good feeding practices, and routine cleaning are the key elements to maintaining excellent water quality. Water temperature is also very important. Species selected for culture must be tolerant of the full range of temperatures experienced at a site, or the temperature must be controlled. Other environmental variables such as lighting (quality, intensity, and photoperiod), current velocity, and vibration must be optimized in order to reduce stress.

General husbandry

Good husbandry practices are a key element to health management. Husbandry is a general term that refers to how the animals are cared for and therefore encompasses many of the topics being discussed. Fish densities must be maintained at a level that is compatible with species tolerance for crowding and the engineered capacity of the system. Physical or visual exposure to potential predators can be a major source of stress to cultured fish. This exposure must be avoided by employing predator nets outside cage systems, and grading fish to reduce cannibalism in tank systems. Whenever fish are handled (e.g. for grading), techniques must be used that minimize stress and physical trauma to the fish’s protective mucous layer. Examples of these techniques include keeping the fish suspended in water whenever possible, and using knotless mesh nets and commercially available mucous-restoring compounds. Culture systems are sterilized between crops. Cage nets are cleaned and sites are left to fallow for several weeks prior to restocking.

Feeding and nutrition

Good nutrition is the foundation for a healthy fish and fast growth. Fish are fed only fresh, high quality feeds. Hand feeding allows daily assessment of the activity level, health status, and satiation level of the fish. Multiple feedings throughout the day are often facilitated by automatic feed delivery systems. Feeding schedules are adjusted to match the activity patterns of the fish.

Prophylactic measures

At the present time little is done in the way of prophylaxis. This is due largely to the fact that the marine finfish culture industry is new and species-specific prophylactic treatments (e.g. vaccines) have not been developed. Newly spawned eggs are immersed in a dilute formalin bath as a prophylactic treatment. The formalin rids the surface of bacteria and fungi and ensures that potential pathogens are not transferred from the (tolerant) adults to the (sensitive) larvae at hatching.

Disease Identification and Diagnosis

The HSWRI aquaculture program has developed a tier system of expertise to assist with identification and diagnosis of diseases. The tier system is designed to meet the specific challenges associated with a disease outbreak – from simple to complex.

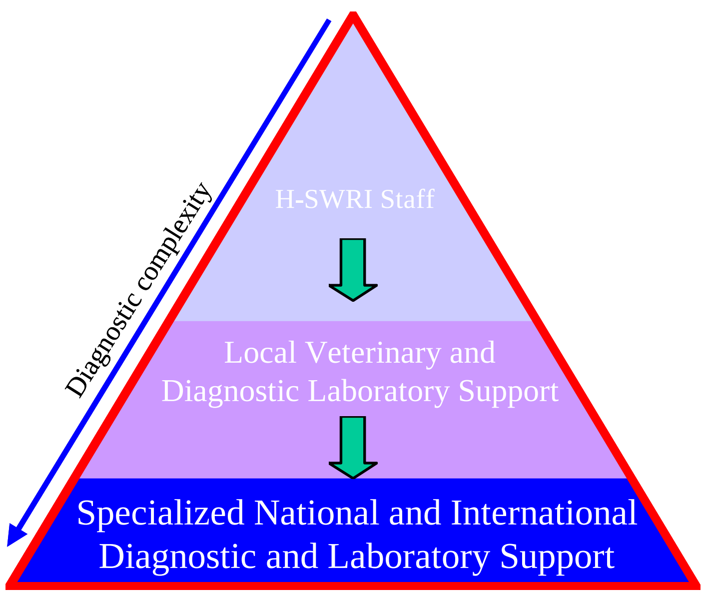


Figure III.2. Tier structure for disease diagnosis in HSWRI aquaculture program.

Technical staff is well trained to detect the early signs of a disease outbreak. Changes in fish behavior (e.g. feeding and swimming patterns) or physical appearance (e.g. coloration and condition factor) are good indicators of stress. Culture managers are further trained in basic examination and necropsy procedures, as well as disease identification. HSWRI laboratories are equipped with basic diagnostic tools to evaluate and identify disease organisms. On-site inspections and staff training are further supported by monthly site visits by a licensed veterinarian, whose services are maintained on retainer. The majority (>95%) of disease incidences are recurring and the pathogenic organisms responsible for the outbreak (typically bacteria or parasites) can readily be identified by trained staff.

Table III.1. List of diagnostic resources and health-related research collaborators currently involved with the HSWRI aquaculture programs.

Local	
SeaWorld of California	San Diego, CA
Avian & Exotic Animal Hospital	San Diego, CA
California Department of Fish and Game	Oceanside, CA
Regional	
University of California, Davis	Davis, CA
University of California, Irvine	Irvine, CA
National	
University of Wisconsin	Madison, WI
International	
Hiroshima University	Hiroshima, Japan
University of Guelph	Guelph, Canada
Fish Health Management	Hamilton, Canada

When the source of a disease cannot be easily identified, whole fish or tissue samples are preserved and sent to one or more of several private, government, or university-based diagnostic facilities. Culture managers are well trained in proper techniques for collecting and preserving samples. Overnight, airfreight services further expedite diagnostic processes. HSWRI has developed relationships with this network of diagnostic facilities during the past 20 years of culture research. Because of these close relationships, a quick turn-around, accurate results, and expert interpretation are ensured. Several labs are utilized depending on the suspected nature of the disease. In addition to basic diagnostic capabilities, each laboratory has its own area of specialization. In some cases specialty services include sophisticated detection tools for specific pathogens that would otherwise be undetectable.

Once the disease organism is identified, a course of action and treatment plan is developed in consultation with one or more licensed veterinarians.

Disease Control and Eradication

In the event of a disease outbreak, spreading is controlled to every extent possible by isolation and quarantine. The application of antibiotics and chemicals to control disease is governed by the U.S. Food and Drug Administration's (FDA's) Center for Veterinary Medicine (CVM), and is limited to 1) approved drugs, 2) special category and low regulatory priority compounds, 3) veterinarian prescription by "extra label use", and 4) Investigational New Animal Drug (INAD) research programs. In addition to approved drugs, HSWRI is actively participating in federally-regulated research programs to evaluate the efficacy of other drugs (Table 2). Depending on the drug used, it may be administered as a bath, in the feed, or injected.

Table III.2. List of drugs currently in use or under evaluation by HSWRI

Drug	Category	Indication	Application	Dosage
Formalin	Approved	Prophylactic treatment of fish eggs; Ectoparasite control	Bath	100 ppm
Tricaine methanesulfonate	Approved	General anesthetic	Bath	50 – 150 ppm
Hydrogen peroxide	Extra-label use	Antibacterial and antiparasitic	Bath	50 – 150 ppm
Romet	Extra-label use	Antibiotic	Feed	50 mg/kg
Oxytetracycline	INAD	Antibiotic	Feed	250 mg/kg
Florfenicol	INAD	Antibiotic	Feed	10 mg/kg

APPENDIX IV. RISKS AND RISK MANAGEMENT

Risks and Risk Management

Extreme Weather

Working offshore in potentially hostile ocean conditions represents a potential risk to any ocean farm. Damage from storms can lead to equipment damage, physical injury and loss of stock. These risks can be mitigated if the appropriate equipment, engineering and experience is matched to the site-specific ocean conditions.

The project will use sea cages that have been proven effective in hostile, offshore environments. This includes withstanding hurricanes and typhoons, as well as routine currents of up to 4 knots and seas in excess of 8 m. Project personnel have direct experience working with these types of systems in harsh environments. The equipment is off-the-shelf technology, and available for all phases of production. Critical to the success of these systems are their associated mooring and anchoring configurations. Project personnel, equipment manufacturers and local marine contractors are working together to ensure that the appropriate mooring system is selected and installed properly according to site-specific characteristics. All installations will be inspected on a regular basis and after storm events.

Pollution

Pollution in the form of land-based discharges and harmful algal blooms (HABs) represents a potential risk to livestock in ocean farms. These risks can be mitigated in a variety of ways that include 1) siting the farm outside the range of discharge plumes and HABs, 2) working with species that are more tolerant to HABs, 3) using submerged cages to keep the fish below the affected surface layer, and 4) having a quick response plan that allows cages to be moved outside the polluted zone.

The project plan will be to site the cages to avoid pollution events in pristine waters that are outside the coastal zone. The coastline of southern California is well studied, so that the characteristics of pollution plumes are well documented and have been modeled relative to seasonal currents and storm effects. This information exists within the public domain and will be used in the review of the potential farm sites. In addition, striped bass are known to be tolerant of various pollutants, including HABs.

Predation

The risk of fish loss or system damage from predators and vandals is a risk to ocean farms. Potential predators encompass four main categories: sharks, marine mammals, birds and people. The risk of predation can be mitigated by 1) removing mortalities routinely from the cages, 2) using anti-predator devices, and 3) having a comprehensive and responsive security program.

The project plan will use a combination of each of these measures. Sharks and other predators are commonly attracted to sea cages that have dead fish on the bottom or an excess of feed that has fallen through the mesh. Proper management and implementation of good biosecurity practices are the simplest, most effective methods of predator deterrence. Project staff has experience in these areas and will implement best management practices into all daily routines to ensure that predator interactions are avoided and optimal husbandry requirements are met.

An anti-predator net will be used that consists of a larger mesh size net that is installed on the outside of the primary fish containment net. Approximately one meter of distance remains between the primary and anti-predator nets. Primary nets typically taper toward the bottom to allow an even larger distance between the two nets. Anti-predator nets are installed on the outside collar of a double collar cage and on the outer edge of a single collar cage. Primary nets are attached to the inside collar of double or single collar cages. The proposed project will install anti-predator nets with mesh sized to ensure an uninterrupted flow of water through the cage and the deterrence of the range of predators in that area without the possibility of allowing entanglement. Predator nets typically range from 8 to 20 cm stretch mesh. The project plans to use 8 cm predator nets.

The California sea lion is commonly found in colonies along the southern California coast and is known to haul out on navigation buoys and other types of floating surfaces. Anti-predator nets will help deter sea lions from the sea cages beneath the surface. A simple net "fence" will be installed around the cage collar at the surface so that sea lions will not be allowed on the cage structure and to prevent them from being able to jump inside. This method is simple and has been proven effective on marine cage farms located in Mexico.

Many types of birds can be attracted to marine cage sites as a resting place and a potential source of food. When fish feed is delivered at the surface, birds have a chance to eat it before the fish can. Net material is typically stretched over the top of the cage and attached to the handrails of the cage collar to prevent birds from feeding on fish food or from preying on fish that have to come to the surface to take the fish feed. Mesh is taut and of a size that birds cannot get entangled. These "bird nets" will be installed on cages used for this project.

People are often the biggest form of predation on some farm sites. The project will have security staff present 24 hours a day on a moored vessel. Constant security will decrease the risk of any vandalism or theft.

APPENDIX V. STRIPED BASS (MORONE SAXATILIS)

Striped Bass (Morone saxatilis)

Species Description and Taxonomy

Striped bass is a member of the family Moronidae, which consists of temperate water basses. Striped bass are so named because of their distinctive black horizontal striping that covers their silvery body. They reach an impressive size of 57 kg and live to 30 years.

Distribution and Abundance

Striped bass are anadromous, which means that they spend their adult life primarily in ocean waters except when they move into river systems to spawn. Some populations of striped bass are land-locked in freshwater lakes and reservoirs. The historical distribution of striped bass was from the Saint Lawrence River in Canada to the Saint John's River in northern Florida, and in the northern Gulf of Mexico; from fresh and brackish tributaries of western Florida to Louisiana. Several hundred striped bass were introduced into San Francisco Bay in 1879 and 1891, where in only ten years they proliferated into an important, self-sustaining fishery that remains today. The primary fishery is in central California but striped bass are now found from northern Baja California, Mexico to the Columbia River in Oregon. Striped bass have subsequently been imported in a number of foreign countries.

Fishery Information

Since the earliest colonial times the striped bass fishery has been an important commercial, recreational and socio-economic resource on the eastern seaboard of the United States. The first laws to conserve striped bass stocks were written in 1639. For more than 100 years the literature has discussed the negative effects of man-made disturbances on striped bass populations, citing excessive harvesting practices, habitat destruction and pollution as primary causes. In recent years these factors have raised alarm in some areas as populations declined to historically low levels. Striped bass populations have been managed regionally by the Atlantic States Marine Fisheries Commission (ASMFC) since its inception in 1942.

On the east coast, commercial harvests of striped bass peaked in the 1970's at 6,000 MT before declining to a low of several hundred MT in the mid to late 1980's (Error! Reference source not found.). Subsequent recovery efforts have paid huge dividends and the fishery was declared "restored" in 1995. Current regulations are very complex as each of the 14 coastal states has its own management measures, in addition to federal regulations outside of state waters. Commercial fisheries occur in 8 of the 14 states. Size limits are typically 71 cm (28")

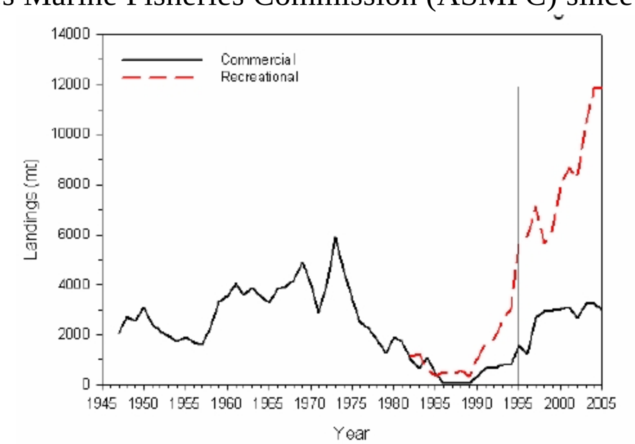


Figure V.1. Commercial and recreational landings of Atlantic striped bass. The vertical line indicates the year the stock was declared restored.

or greater, with 46 cm (18”) in some areas like the Chesapeake Bay. Seasonal limits also vary widely but in general striped bass are caught legally year-round.

On the west coast, commercial harvests peaked in 1903 at 900 MT after which time fishing regulations reduced catches. In 1935 the commercial fishery was closed because of the conflict between recreational and commercial fishermen. Recreational catches of striped bass peaked in the 1960’s at approximately 750,000 fish per year and are currently at approximately 200,000 fish per year. Currently there is a 46 cm (18”) minimum size limit north of Point Conception and no size limit to the south. The season is open year-round with a bag limit of two fish per day.

Aquaculture Information

Striped bass have a long culture history dating back to 1884 when ripe brood fish were strip-spawned into hatching jars by culturists at the U.S. Fish Commission hatchery in Weldon, North Carolina. During the first year of operation, 2.4 million eggs were collected and hatched to yield 280,000 viable fry that were released into the Roanoke River. During the late 1960’s and early 1970’s significant breakthroughs in artificially induced spawning using hormone injections catapulted the industry and led to the development of additional striped bass hatcheries. Most of the fingerling production was used to support stock replenishment efforts.

In the late 1980’s the culture of striped bass hybrids began and developed rapidly into the primary form of striped bass culture in the United States. Hybrid striped bass are created by fertilizing female white bass (Morone chrysops) eggs with sperm from male striped bass (Morone saxatilis). The resultant cross is sometimes called a sunshine bass or reciprocal cross hybrid striped bass. Unlike pure striped bass, the horizontal stripes of the sunshine bass are broken and not continuous. The hybrid striped bass is more tolerant to extremes in temperature and dissolved oxygen than either parental strain, which makes it better suited for pond culture. In 2004 hybrid striped bass was nearly a 5200 MT industry in the United States. Production was generated by 61 facilities across the country divided into ponds (44) yielding 3200 MT, tanks (7) yielding 1900 MT and cages (10) yielding 59 MT. The culture of pure strain striped bass has largely been curtailed even for replenishment, although the capabilities to produce fingerlings is still available because the broodstock are used to produce the hybrids.

Biology

Maturity and Reproduction

In California, striped bass begin spawning in the spring when the water temperature reaches 15.5°C. They spawn in fresh water where there is at least a moderate current. Females spawn for the first time when they are five years old at a size of approximately 61 cm (24”). Males mature when they are 2-3 years old at a size as small as 28 cm (11”). Striped bass are highly fecund with young mature fish producing 250,000 eggs per year and older fish producing several million eggs. Illustrative of their reproductive capacity is how quickly they established themselves in California. Spawning of striped bass is induced using hormones.

Environmental Requirements

Striped bass juveniles adapt readily to a range of salinities from fresh water to full ocean conditions. Their ability to adapt rapidly, within 24 hours, to this full range of salinity is quite remarkable. Juveniles thrive in temperatures of 18-23 °C but tolerate a much greater range. They are known to successfully over-winter under ice in cages. Optimum growth is reported to occur at approximately 24 °C, although different strains can be expected to have different thermal optima given their broad latitudinal distribution.

Growth and Food Conversion

Striped bass exhibit good growth rates and are known to reach a size of 1.0 kg in two years in tanks based on actual data from striped bass grown at HSWRI in tanks. Growth rates of pure striped bass in open ocean cages has not been reported in the literature. However, preliminary data from HSWRI's joint project with Maricultura Del Norte in Ensenada, which is currently growing striped bass in two different types of ocean cages, reveals striped bass growth in cages are on a similar tract as those grown in tanks. Food conversion rates of <1.5 are routinely achieved.

Diseases

Various diseases of striped bass and its hybrids are documented extensively in the literature. However, HSWRI's experience with striped bass has found them to be remarkably resilient to diseases when cultured in water temperatures of 10-22°C, even under very crowded conditions. Exposure to crowding, handling or other stressors in warmer water often results in bacterial infections of the caudal fin referred to as "red tail" or "tail rot". Red tail can be readily treated with medicated feed.