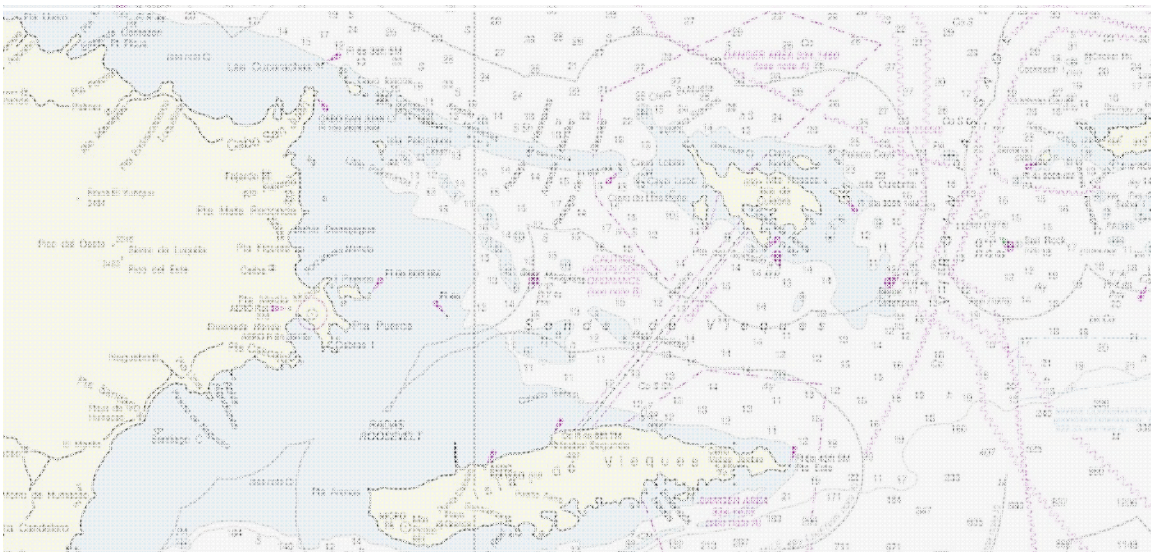
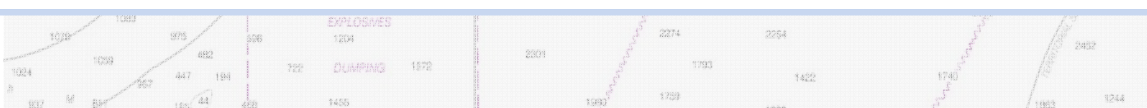
Best Management Practices for Marine Cage Culture Operations in the U.S. Caribbean





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Best Management Practices
for Marine Cage Culture Operations in the U.S. Caribbean

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INTRODUCTION

David O'Brien
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"To ensure that ecological well-being is compatible with human well-being, and to make long-term sustainable prosperity a reality for all, it is necessary to strike the right balance between seizing opportunities and addressing threats in the use of technology and natural resources, in applying sound economic and policy decisions and in preserving environmental integrity and social license."

Árni M. Mathiesen,
Assistant Director-General
United Nations
Food and Agriculture Organization

Over the past four decades marine aquaculture has grown rapidly around the world as countries and individual companies seek opportunities to produce more seafood for local consumption and export markets. The increase in global aquaculture production during this time has been dramatic, expanding from less than 5 million metric tons (mmt) in the mid-1970s to 60 mmt in 2010, with aquaculture products now comprising approximately half of all seafood we eat. The global aquaculture industry is expected to continue its expansion, and the purpose of this document is to provide guidelines for stakeholders committed to sustainable marine aquaculture which safeguards the ocean.

While demand for seafood continues to increase, harvest fisheries have plateaued. As most wild fish stocks are either fully or overexploited, any significant increase in seafood supply will likely come from aquaculture production. Expansion of freshwater aquaculture may be limited due to competition for available land and water from agriculture and other uses. With technologies and equipment now being developed to withstand harsh ocean environments, there is an increasing interest in coastal and offshore marine aquaculture.

Past and current marine aquaculture practices have demonstrated the need for proper siting and management to avoid negative impacts to the marine environment while ensuring optimal growing conditions. Early efforts to develop marine aquaculture did not always give sufficient consideration to potential negative impacts, resulting in environmental effects, such as destruction of marine habitats, introduction of non-native species, eutrophication, and disease outbreaks. In some parts of the world, concerns remain about marine aquaculture practices, such as improper siting or management protocols that continue to pose a risk to marine environments. Coastal managers and communities must balance the risks of marine aquaculture with its benefits including job creation, reducing seafood imports, and enhancing food security.

Examples from the U.S. and elsewhere demonstrate that properly sited and managed marine aquaculture operations meet environmental regulatory requirements and can be environmentally sustainable while coexisting with other coastal uses. Modern, effective management tools include models to predict impacts to water quality and benthic environments, standardized monitoring protocols, biosecurity, integrated pest management, vaccines that reduce or eliminate the need to use antibiotics and other therapeutants, consideration of genetic impacts to wild populations, and improved cage systems and fish handling practices to reduce the incidence of escapes. In Maine, Washington, Hawaii, and elsewhere, state and federal agencies have worked with industry to develop permitting and management systems that make the U.S. aquaculture industry one of the most environmentally responsible in the world. When coastal managers are provided appropriate tools, marine aquaculture can produce domestic seafood while providing economic opportunities to coastal communities and maintaining healthy oceans.

There is interest in the U.S. Caribbean in establishing a marine aquaculture industry to produce seafood for local and export markets. For example, the company Snapperfarm, Inc. established a cobia cage culture operation off the island of Culebra in Puerto Rico in 2003. Subsequent efforts to obtain a permit to expand were not successful, and the company shifted operations to Panama in 2009. While no marine finfish cage culture operations currently operate in the U.S. Caribbean, potential investors remain interested in the industry once the permitting process is more straightforward.

Given the presence of sensitive coral reef habitats in the area, coastal managers and researchers, including members the U.S. Coral Reef Task Force, expressed concern about the environmental risks of marine finfish cage culture in and near coral habitats, and have highlighted the need for comprehensive management strategies to mitigate potential negative impacts. Currently, environmental reviews of marine aquaculture permits in the U.S. Caribbean are addressed on a case-by-case basis. Representatives from the aquaculture industry and coastal managers agree that Best Management Practices (BMPs) for marine cage culture operations would provide a valuable standard reference to assess aquaculture permit applications and refine permit criteria.

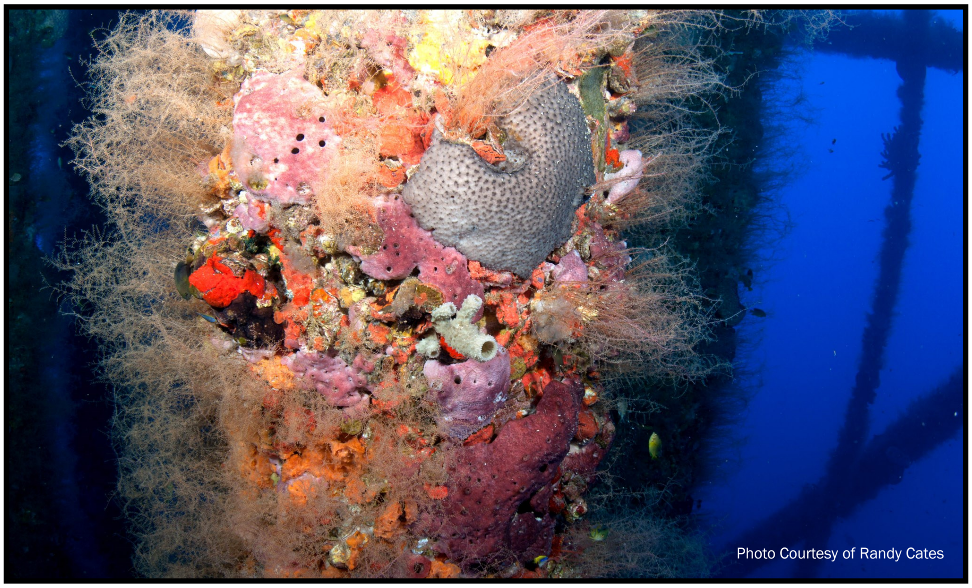
In 2010, the Puerto Rico Department of Natural and Environmental Resources and the National Oceanic and Atmospheric Administration (NOAA) convened a workshop in conjunction with the 63rd Gulf and Caribbean Fisheries Institute meeting in San Juan, Puerto Rico to begin developing BMPs for marine cage culture operations in the U.S. Caribbean, with emphasis on reducing impacts to coral reef habitats. The workshop participants included managers from federal, state, and territory regulatory agencies, researchers, university professors, representatives from environmental organizations, and the aquaculture industry. The participants included experts in the regulatory processes, coral reef ecology, marine habitat monitoring and assessment, water quality and benthic modeling, and marine aquaculture.

The goal of the workshop was to produce an initial list of key elements to include in the BMPs that would reduce potential impacts to coral ecosystems from marine finfish aquaculture (Appendix IV, Table 1) and identify management tools that reduce or eliminate environmental impacts. The outcomes of this workshop formed the basis upon which these BMPs were further developed by teams of experts working together to craft each chapter. Once the chapters were completed and compiled, over 20 expert reviewers, most of whom participated in the workshop, provided input to improve and refine the final BMP report. These BMPs represent guidelines, developed collaboratively by a diverse stakeholder group, that can be voluntarily implemented at marine cage culture operations in U.S. territorial waters of the Caribbean.

These Best Management Practices will be useful to many stakeholders. Farm owners and operators can apply them to guide siting and farm management practices. Coastal managers and community planners can use this information to make environmentally responsible decisions about the economic opportunities that aquaculture offers. Federal, state, and local regulatory agencies can consider these practices as they develop and implement permitting and monitoring processes for the Caribbean offshore aquaculture industry. These Best Management Practices are a tool for implementing responsible marine cage culture which safeguards and maintains healthy ocean ecosystems.

1. ECOLOGICAL EFFECTS

Carol Price
NOAA National Ocean Service



Marine cage culture operations can have a variety of ecological effects on the marine environment, including nutrient enrichment to the water column and sediments, and effects on biodiversity and sensitive habitats. Identifying potential site-specific ecological impacts prior to initiating farm operations will help build awareness of how the farm may interact in the marine environment. Nutrients (primarily carbon, nitrogen, and phosphorus) are typically discharged as excess feed particles or as fish waste, resulting in a series of chemical and biological responses. Under natural conditions, organic waste that settles on the ocean floor is consumed by bottom feeding animals or decomposed by bacteria. Organisms living in and on the sediment take up the nutrients, promoting a diversity of plants and animals. However, if too much organic waste accumulates, chemical and biological processes shift to an anaerobic state in which there is little or no oxygen available. This can lead to a decline in the diversity of the benthic community, or under severe loading conditions, entirely denude the benthic community in the impact zone. Proper siting of farms in well-flushed areas can help minimize nutrient accumulation and reduce or eliminate effects to the benthic community.

When accumulation occurs, effects are usually confined within 100 meters of the farm area. However, several management options can be proactively implemented to minimize nutrient loading and prevent secondary and long-term ecological effects. For example, siting operations in deep, well flushed areas will help to disperse nutrients away from the farm site. The use of modern feeds formulated to be efficiently digested by the cultured fish can also help decrease waste, as does careful monitoring of feeding events to ensure that food delivery ceases once fish have stopped eating.

Sediment monitoring protocols should always be followed to ensure early detection of excessive nutrient loads or anoxia, and implementation of adaptive management alternatives, including follow-up monitoring. Site planning should include cage rotation or a fallowing plan in the event that there is measurable impact to the sediment. This will allow for chemical and biological recovery prior to restocking and usually takes less than two years.

Cleaning nets and cages during slack currents can result in a nutrient load to sediments as detritus and organisms sink to the sea floor and decompose. Alternatives include cleaning nets or cages onshore or during periods of moderate currents to disperse nutrients. Some cage designs also allow for partial air drying of nets during deployment to help keep fouling organisms in check.

Antifoulant chemicals used on nets or cages may also contain copper. This approach is largely being replaced with mechanical scrubbing of nets (onshore, where possible) or with air drying, thereby greatly reducing the amount of copper deposited and detected in sediments. Other heavy metals, notably zinc, are present in feed in small quantities. Efficient feed formulation and good feed management practices can help reduce the amount of excess feed being discharged, resulting in a reduction in the amount of heavy metals released into the environment. Heavy metals may be chemically bound in sediment samples making them unavailable for uptake into the food web, and thus monitoring protocols which include detection of heavy metals is recommended.

When low or moderate levels of nutrients are released, this can serve as food for other species in or around fish cages. In some cases, an increase in the abundance of benthic organisms underneath nets or cages has been reported, indicating that nutrients are being incorporated into the food chain. It is also common for wild fish to aggregate beneath cages to scavenge for food or seek shelter. These wild fish may in turn attract other predators such as dolphins and sharks to the farm area. These predators can sometimes damage net pens and cages when attempting to reach the cultured fish or any dead fish inside the structure. Effective predator deterrent measures include installing predator nets, using rigid cage material, and removing dead fish in a timely manner. Acoustic devices to deter predators are often effective when they are first installed, but target animals can quickly become accustomed to them. There are few reports of farms negatively impacting other protected marine species, such as sea birds, sea turtles, and whales, and siting farms away from known migration corridors will minimize most interactions with these species. The possibility of entanglement can be decreased by keeping net and cage lines taut, and vessels can avoid collisions with sea turtles and marine mammals by operating in a careful and cautious manner.

In the U.S. Caribbean, special attention must be given to the potential impacts of siting farms near sensitive ecosystems, including coral, seagrass, and mangrove habitats. These ecosystems are very sensitive to sedimentation and nutrient loading, and this is especially true for coastal areas with residential development and multiple sources of point and non-point source nutrient loading. Submerged habitats also can be damaged during farm installation and may be sensitive to shading from net pens, cages, and other moored structures. As a result, marine cage culture operations should be sited away from these sensitive habitats. In places were farms are located up current of potentially sensitive habitat, water quality and benthic monitoring protocols should include provisions for early detection of impacts. It should also be noted that storm events may re-suspend nutrients or chemicals in the sediment and transport them considerable distances from the original farm footprint, and this should be taken into account during the siting process.

Best Management Practices for Ecological Effects

1. Optimize feeding protocols,
2. Minimize nutrient accumulation at the site,
3. Implement cage rotation or fallowing if nutrient loading exceeds ecological threshold,
4. Avoid disruption to native biodiversity, especially protected species,
5. Prevent predator interactions and use non-lethal predator deterrents, when necessary,
6. Employ methods to minimize physical disturbance to habitat,
7. Utilize responsible cage cleaning methods,
8. Use proper cage design to minimize entanglement with marine animals and other protected species,
9. Site farms away from corals, seagrass, mangroves, and other sensitive habitats, and
10. Exercise caution when operating vessels to avoid collisions with sea turtles and marine mammals.

2. WATER QUALITY

Carol Price
NOAA National Ocean Service

Maintaining good water quality around marine cage culture operations is important to maintain the marine ecosystem as well as the health of the fish in the cages. Dissolved nitrogen and phosphorus from excess feed and fish waste are released and dispersed from the farm area into the surrounding water column. As a result, dissolved oxygen levels may decrease as cultured fish respire, especially after feeding times, but typically not below levels that result in significant ecological effects. At properly sited and well-managed farms, it is unlikely that algal blooms will occur, even when nutrients are discharged.

Methods used to clean nets and cages also may impact water quality. For example, nets or cages may be treated with copper-based antifoulants or pesticides which can slowly leach into the surrounding water and are toxic to many species of marine life. If possible, chemicals should be avoided and alternative, non-chemical methods to remove fouling should be employed. This could include mechanical scrubbing by divers, drying and cleaning on land, or partially lifting cages or nets out of the water column to expose fouling organisms to desiccation. Onsite cleaning may also result in an increase in the load of organic material to the benthos. However, as long as the farm is located in a properly flushed site with healthy sediment decomposition processes, effects should be minimal and of short duration.

Properly siting marine aquaculture operations in deep, well-flushed waters can greatly reduce the likelihood of negative impacts to surrounding water quality. Using formulated feeds and adhering to good feed management practices can reduce metabolic waste. Some farms may install underwater cameras to monitor feeding and fish activity, thus further reducing nutrient discharge to the water column.

Reducing waste and debris at farm sites can also contribute to cleaner water conditions. For example, removing dead fish in a timely manner will avoid fouling the water column, help deter predators, and prevent spread of disease. Additionally, employing clean harvest and slaughter methods will also prevent the discharge of fish processing waste. While chemical use at farm sites is often minimal, a chemical spill response plan is recommended in the event that an unintentional spill of fuel or other chemical occurs. Farm vessels should be properly maintained and operated in order to minimize leaks, spills, and loss of waste or debris overboard, and daily routines should include transporting trash and debris to shore for proper disposal.

Water quality impacts may be further reduced through the use of integrated multi-trophic aquaculture (IMTA), i.e., the practice of culturing finfish in combination with other species that filter waste particulates and absorb dissolved nutrients. In some cases, this approach has the potential to mitigate environmental discharge while also expanding the economic base of a farming operation. Shellfish including mussels and oysters, and seaweed are common species for IMTA, and trials with lobsters and sea urchins have met with some success. Nevertheless, IMTA is an experimental element of sustainable marine aquaculture and in some cases can increase the social acceptance of marine aquaculture.

While it is unlikely that fish farms would be permitted in areas directly over or adjacent to corals, seagrass, and mangroves, in the case that farms are sited upstream of one of these essential marine habitats, additional water quality monitoring in those locations is recommended (and could be required by regulatory agencies) for early detection of impacts. Scientific studies have documented that these sensitive habitats can be negatively affected by farms, but that proper siting can prevent harmful impacts. While impacts to nearshore coral reefs, seagrasses, and mangroves can be eliminated by siting farming operations in offshore areas, impacts to deep corals should still be considered.

Best Management Practices for Water Quality

1. Establish nutrient and water quality thresholds,
2. Tailor monitoring plan(s) to take into account impacts to sensitive marine habitats,
3. Consider the use of integrated multi-trophic aquaculture, when practicable,
4. Discourage the use of chemical antifoulants and employ mechanical cleaning methods, when possible,
5. Quickly remove and properly dispose of fish mortalities,
6. Encourage clean harvest methods and off-site processing,
7. Collect operational and human waste for off-site disposal,
8. Take measures to prevent discharge of contaminants from farm and develop a chemical spill response plan,
9. Properly maintain and operate farm vessels and equipment to minimize leaks, spills, or waste loss, and
10. Provide employees with approved marine sanitation devices aboard vessels or working platforms.

3. ESCAPES

Michael Rust
NOAA National Marine Fisheries Service

Escape prevention and mitigation plans should be developed for every aquaculture operation, including preventative and recapture or mitigation strategies if escape occurs. These plans should consider grow-out and fingerling sourcing (hatchery) decisions. In most cases, multiple options exist to reduce risk, but risk management strategies that improve economic gain and reduce or eliminate environmental impacts have a higher chance of resulting in adoption by industry and making meaningful improvements. Furthermore, strategies that allow improvement or change over the long term provide more flexible, adaptable, and realistic solutions.

Escapes of fish raised in aquaculture can present two basic risks to wild populations — ecological and genetic. For offshore and near shore cage culture operations, choosing appropriate cage technology for the area, routine inspection, and good maintenance are critical for reducing or eliminating escapes. Regular monitoring of the farm is critical for knowing when an escape occurs so that corrective activities can be undertaken. This approach has resulted in significant reductions in escapes from U.S. salmon farms. Escapes plans should include specific actions to measure and reduce leakage (frequent, small escapes) in addition to catastrophic escapes (infrequent, large escapes).

The release of fertilized eggs or larvae into the ocean is a concern. Actions taken to mitigate or eliminate cage spawning depend on the life history and physiology of the species being cultured and include:

- i) Harvesting prior to sexual maturation,
- ii) Dietary manipulation or maintaining environmental conditions to delay, reduce or prevent sexual maturation, or
- iii) Using sterile or monosex fish.

A specific section in the farm's escape prevention and mitigation plan should be developed to address this issue. Other ecological risks include 1) disease transmission by escaped aquaculture fish to wild fish, and 2) risks due to establishment of exotic species from escapees. The first issue is addressed in Section 4.

The second risk can be addressed by culturing local species that are native or naturalized to the geographic region in which the aquaculture operation is located. Culture of native species presents a genetic risk when escaped farmed fish spawn with wild conspecifics, potentially resulting in loss of fitness in the mixed population if the numbers of wild conspecifics are small. The magnitude of the fitness impact caused by interbreeding between domesticated and wild stocks can be difficult to detect and predict. Computer models developed to manage stock enhancement hatcheries are being modified to predict the degree of fitness loss associated with escaped aquaculture organisms. Though still untested, these models will eventually help assess the potential impacts due to escapes of various sizes and durations.

The genetic risk of fitness loss associated with escape of a cultured native species is a function of:

- i) The number of escapes relative to the number of wild conspecifics,
- ii) The genetic differences between wild and escaped populations, and
- iii) The ability of the escapees to successfully reproduce in the wild (reproductive fitness).

This understanding can be used to target strategies for risk reduction associated with escapes. Choosing locally abundant species for culture or ensuring a low number of escaped fish relative to the size of the wild population (to keep the ratio of escapes to wild spawners low) can reduce risk. Genetic risks can be reduced with an integration approach that uses broodstock with a genetic make-up similar to local wild stocks so that the impact from farm escapes mating with wild animals is reduced. This can be done by using wild fish from the local population as founding broodstock. Alternatively, the segregation approach means domesticating farmed species to a level that significantly reduces the escapees' fitness to reproduce in the wild. A strategy that combines two or more of the above strategies may be the most effective and tradeoffs should be evaluated.

Using local wild fish as broodstock would enable a hatchery to more easily maintain a wild-like genetic make-up in its cultured progeny, whereas selective breeding would tend to narrow the genetic diversity relative to the wild type. However, maintaining a wild-type genotype on the farm may also forgo benefits of selective breeding such as fish that metabolize feeds more efficiently, accept alternative feedstuffs more readily (e.g., plant-based proteins), exhibit higher disease resistance in an intensive aquaculture setting, and grow faster. Moreover, maintaining a wild genotype in fish stocked in offshore cages can be at odds with economic goals, reducing the chance for industry adoption and meaningful environmental risk management. Research and models to address these trade-offs are an active area of scientific investigation. An adaptive management approach might be warranted where operations start with the local wild stock as brood and then evaluate the relative benefits and risks of the integration or segregation approaches.

Ecological and genetic risks can be eliminated or reduced by using sterile fish. Current sterilization techniques (e.g., polyploidy, hybridization, chemical sterilization, etc.) are about 99% effective for many cultured species. However, this approach may increase the cost of fingerling production or reduce fish performance in culture. These drawbacks must be offset by some economic benefit to the hatchery to justify the extra work and cost to create sterile fish. While this is an approach worth considering, its applicability depends on factors specific to the species being considered (e.g., most effective method of sterilization) and economic considerations of the breeding operation.

Non-local, or exotic species are generally discouraged for fish farming in marine environments. However, if exotic species are considered, an extensive risk assessment is recommended, to develop steps to prevent escape.

Best Management Practices for Escapes

1. Develop and regularly update an escapes reduction and mitigation plan for each farm,
2. Use cage designs which minimize the possibility of escape,
3. Routinely monitor cages for escapement and properly maintain cage equipment,
4. Take measures to avoid unintended releases of cultured gametes, eggs, and larvae,
5. Culture local (native or naturalized) species and discourage or prohibit the culture of non-native species,
6. Require risk assessment for non-local species,
7. Develop a broodstock program that conserves genetic diversity (integrated approach) or selects for low wild fitness (segregated approach), and
8. Consider stocking sterile fish, when practicable.

4. FISH HEALTH

Kevin Amos
NOAA National Marine Fisheries Service

A successful cage culture operation must maintain conditions for optimum health of the cultured animals to promote performance and growth, make the best use of nutrients and feed, and avoid infectious and non-infectious diseases.

A healthy fish looks good and is good to eat. A farm health management and monitoring plan includes information about which species are cultured, their rearing densities, diet and feed management, and harvest schedule. Fish should originate from healthy broodstock of a sound genetic strain. Larvae or fingerlings should be inspected prior to transport and stocking to assure they are in good health and free from disease and parasites.

Implementing proactive measures to prevent disease is a first step in establishing and maintaining healthy fish. The water at the rearing site should flow freely through the cage and be clean, oxygen rich, and free of pollutants. Without a healthy, clean cage environment fish can soon become stressed or sick, resulting in poor health, impaired growth, and possibly death.

Control of biofouling organisms is important as their buildup can impede water flow. The cage material must be maintained to prevent abrasion and escape. Dead fish should be removed from the cage as soon as possible, counted, and inspected for signs of the cause of death. Dead fish should not be left in the cage to avoid fouling of the cage, spread of disease, and predator attraction.

A health monitoring plan and associated protocols include a regular daily evaluation of the overall health of the fish. Farm personnel should note if the fish are hungry and behaving normally. Keeping daily feeding records for each cage is imperative. A growth chart that prescribes how much the fish are expected to eat and grow within a certain period is useful for monitoring fish performance and detecting early signs of problems. Even if fish appear healthy, keeping good records of feed consumption and growth will establish if their growth is meeting production expectations.

Fish health may be compromised by both infectious (bacteria, virus, parasites) and non-infectious (nutritional, environmental) causes. An accredited health professional should be available to the farm operators to regularly examine fish to determine if disease is an issue. Routine visits and examination of fish — even if the animals appear healthy — are encouraged. Veterinarians with expertise in fish culture or other qualified aquatic animal health experts can suggest ways to improve the performance of the stock and aid in developing a bio-security plan to prevent and control the spread of pathogens within the site or from cage to cage. An overall sanitation scheme should include disinfection of gear, nets, and staff when moving between cages or farm sites.

It is critical not to exceed the optimum loading density, the number and total weight of fish per cubic meter of cage rearing space. This loading rate is both species-specific and fish size-specific. Some fish thrive in large schools while others tend to be more solitary and require more space. Generally, small juvenile fish require more cage space per pound than larger, mature fish. Recommended appropriate loading densities for many cultured species are available in the literature. As fish grow, their environmental needs change. Thus, when fish are first stocked, it must be below optimal loading density to allow the fish to grow into the cage area. Once that optimum is achieved, it is time to harvest or re-distribute the fish to additional pens at lower density to encourage further rapid growth.

Many infectious diseases, primarily those caused by bacteria, are effectively prevented by vaccination. Vaccines and other therapeutants are regulated by the U.S. Department of Agriculture (USDA). An aquatic health specialist can determine if and how a vaccine should best be utilized at a particular cage site. The U.S. Food and Drug Administration (FDA) is responsible for approving drugs for use in aquaculture. The FDA defines drugs as "articles intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease and articles (other than food) intended to affect the structure or any function of the body of man or other animals" [Food, Drug, and Cosmetic Act, sec. 201(g)(1)]. Different types of drugs are administered to aid in spawning, treat systemic infections, remove parasites, or sedate fish for handling. Veterinarians are knowledgeable about the appropriate and legal use of drugs and can prescribe medications, if needed.

If cultured fish have become infected with a disease, it may be necessary to use an antimicrobial (including antibiotics) to control the disease outbreak. Since antibiotics can only be administered to marine fish within the scope of FDA regulations, a licensed veterinarian must prescribe their use. There are several good reasons to minimize the use of antibiotics, including expense and the mandatory withdrawal period of weeks or months before the fish may be harvested and sold for human consumption. Antibiotics may be discharged from cages in uneaten food or feces, possibly impacting other organisms in the surrounding marine environment.

Many aspects of animal health are regulated by local and federal authorities, and it is up to the farm operator to ensure that aquatic animal health protocols are followed. The USDA Animal and Plant Health Inspection Service (APHIS) is responsible for the international and interstate commerce of live farmed animals with regard to controlling spread of certain infectious diseases. Before live fish are shipped to another state or country, they may require an official health inspection and health certificate issued by APHIS. Farm personnel should work with veterinarians and local APHIS officials to determine if and when health certificates are required to transport fish. In some instances when the aquatic animal is destined for retail sale or human consumption in another country, the health certificate may be issued by an inspector from the NOAA Fisheries Office of Seafood Inspection (SIP).

Photo Courtesy of Brian O'Hanlon

If a World Organization for Animal Health (OIE) reportable disease outbreak occurs at the site, it must be reported to APHIS. While the list of OIE reportable diseases for marine fish includes only a few diseases, there may be additional diseases regulated by the local government. Further, it is possible that disease control measures may be required by APHIS to prevent the spread of the disease within a farm or to another nearby site, and it is important that farmers cooperate with APHIS and local authorities during this process. Communication with the designated veterinarian to involve them in any discussions with regulatory agencies regarding the implementation of disease control measures is also important.

Best Management Practices for Fish Health

1. Develop a health monitoring plan and protocols,
2. Consult with an aquatic animal health expert or veterinarian at various levels of operation,
3. Develop and employ biosecurity practices and quarantine protocols,
4. Use appropriate stocking densities and employ techniques to minimize physiological stress to cultured organisms,
5. Vaccinate fish prior to stocking into cages, if available and necessary,
6. Use only FDA-approved drugs,
7. Minimize the use of antimicrobials,
8. Cooperate with animal health regulators, and
9. Coordinate with veterinary, husbandry and fish pathology researchers, when possible.

5. FEEDS

Mike Rust
NOAA National Marine Fisheries Service

A key best management practice for feed is eliminating raw feed ingredients including small fish, fish processing waste, squid, and animal slaughter waste. These can contain pathogens and parasites, are variable and often poor sources of vitamins and minerals, and may contain anti-nutrients (for example, thiaminase) that will cause nutritional deficiencies, lower growth rates, and increase susceptibility to pathogens. Raw feeds disintegrate rapidly in water, reducing water quality and feed efficiency. In contrast, modern pelleted diets are heated during pelleting to temperatures sufficient to eliminate pathogens and parasites. Further, modern pellet feeds are formulated to supply all essential nutrients needed by fish for rapid growth and optimum health. Pelleted feeds are a big step forward economically and environmentally over feeds made from raw ingredients.

Pelleted feed is primarily obtained from feed companies rather than produced on the farm. Hence, the farmer depends on the feed company to formulate and manufacture good quality feeds. The farmer has direct control over feeding practices that impact the economic and environmental performance of the farm. Feed costs typically account for 50 - 60% of the variable operating cost to grow fish in marine net pens, so farmers have a strong economic incentive to optimize feed use. Inexpensive diets can be produced from poor quality feed stuffs, but their lower cost is unlikely to compensate for their reduced performance. In the vast majority of cases, a high quality, high performance diet will be worth the extra cost. Proper feeding in terms of amount fed, how the feed is offered at each feeding and frequency of feeding also affects fish performance and nutrient retention. Since feed is the source of waste nutrients discharged from farms, decreasing the amount of waste feed has both economic and environmental benefits.

Optimizing feed use means closely monitoring the amount of feed used in relation to the amount consumed by the fish and the resulting fish growth. Optimization strategies commonly include hiring experienced feeders, underwater camera systems, pellet detection devices, and computer controlled feeding systems. Regular chemical analysis of feed batches coupled with good feed and fish performance records are helpful. Monitoring can be aided by using floating or slowly sinking pellets so feeding can be easily observed from above or by using underwater cameras to monitor consumption of sinking pellets.

Best Management Practices for feeds include improving feed conversion ratios (FCR) and minimizing wasted feed. It is important to track and analyze records of fish growth, survival, feed consumption, feeding times, and feed amounts. Feeding efficiency should also be evaluated in terms of feed price per unit of growth or feed price per unit of growth per unit time, and not simply as price per ton of feed.

Farmers can help improve feed quality and FCR by working with manufacturers to produce feeds that closely match fish's nutritional requirements, are highly digestible, and are suited to their production methods. Having a choice in feeds and feed suppliers should be encouraged to spur continuous improvement by the feed companies. It is in everyone's best interest to ensure that the feeds being used are nutritionally adequate for the age and size requirements of the species being raised at each developmental stage. Feed formulation, production methodology, proximate composition, and feedstuff quality is largely set by the feed manufacturer. However, farmers can influence quality through their purchasing decisions and by working with manufacturers to refine feeds. Farmers should favor feeds that closely match the animal's nutritional requirements, are highly digestible, and use appropriate production methods. Farmers must clearly communicate their needs for feed specifications such as minimal proximate composition, digestibility, percent fines, and other requirements unique to a species or farming practice to help improve diets for cultured animals.

A great deal of research has been conducted to find alternative protein and lipid sources for fish feeds, which traditionally included high amounts of fish meal and fish oil sourced from wild reduction fisheries. Fish meal remains an economical source of essential nutrients compared to high quality plant-based proteins. While the majority of wild harvested fish stocks used for fish meal and fish oil are considered sustainably managed, this resource is finite and fully utilized. As demand for these resources has increased, prices and concern over the potential to over harvest have increased. Aquaculture's share of these resources increased steadily over the past decades, but has recently declined largely due to development of high quality, lower cost sources of protein and lipids from plants, animal by-products and other sources, and the adaptation of traditional protein and lipid feedstuffs to aquatic animal feeds. Further reduction of fish meal and fish oil in feeds and encouraging the use of feedstuffs from sustainable sources is encouraged. The environmental performance of different feed formulations and manufacturing processes is not straightforward. For example, at the feed production level it might refer to the life-cycle cost of the feedstuffs, energy use, greenhouse gas emissions, or some other metric of environmental performance. This is an area of growing interest, but there are no universal metrics to gauge the environmental performance of a feed based on its formulation, other than to minimize fish meal and fish oil sourced from over harvested stocks.

Most marine fish farms produce seafood for human consumption. Feed choice can impact the final product quality for human health. One priority is to maintain levels of the long chain omega-3 fatty acids equal to or greater than levels in wild caught fish. In species examined so far, the requirements for these fatty acids for fish growth and health are less than the levels needed to produce fillets with omega-3 fatty acid levels with health benefits to people. Therefore, it is possible to rear healthy fish that have an inferior fatty acid profile for consumers. Since it will likely be cheaper to do so, this is one area where economic considerations must be balanced with marketplace demand.

Feed for aquaculture may introduce toxins into seafood for human consumption and must be prevented. Feed produced in the U.S. is subject to FDA regulations. It is prudent to regularly monitor seafood for toxins, and to request feed companies to provide data on toxin levels in the ingredients. In the long run, producing farmed fish products that are nutritionally inferior to wild counterparts or which contain toxins would be detrimental for the aquaculture industry.

Feed is a perishable product, and the importance of proper storage, handling, and use practices cannot be overstated. Storage and handling conditions can impact how quickly feed quality degrades. The storage period should be kept to a minimum to prevent deterioration and damage due to microbes, insects, or rodents. Moldy feed should never be used and may be a health risk for workers. Applying first-in-first-out protocols, conducting inspections, and maintenance of storage facilities will help get the most out of costly feed. In general, don't purchase more feed than will be used in six months, with adjustment down for sub-optimal storage conditions like high temperatures or humidity.

Best Management Practices for Feeds

1. Minimize use of raw or unprocessed feeds,
2. Promote techniques to improve feed conversion ratio and minimize excess feed input,
3. Maintain and analyze records of fish growth, survival, feed used, feeding times, and amounts,
4. Provide feed companies with desired composition, performance and practical feeding requirements (sinking rate, fines, pellet hardness, etc.) for each cultured species and work with them to improve in these areas,
5. Encourage feed companies to use feedstuffs from environmentally responsible sources and practice continuous improvement in all aspects of feed formulation and manufacture,
6. Procure feed with an adequate amount of long chain omega-3 fatty acids to produce a final product with equal or greater levels of these fatty acids compared to that of the same species from the wild,
7. Procure feed with minimal toxins of concern for human health and monitor for key toxins in the product, and
8. Handle and store food appropriately to maintain quality .

6. HUMAN DIMENSIONS

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Ideally, any new marine aquaculture venture should have the support of the local community. Before starting a new marine cage culture operation, the potential impacts on the local community should be identified. Plan to inform the residents about the new industry, including the employment and business opportunities, visual and spatial effects, and other potential concerns that may come with the new business. For example, public hearings could be held prior to applying for permits to address the community's concerns, answer questions, and alleviate possible fears about the proposed aquaculture operation.

In aquaculture, as with any other production activity, the success of the operation depends on the expertise of those who will operate it. Each operation should conduct a personnel assessment to determine if they have the necessary manpower for their operation. In addition, it is important to identify local, regional, or national workforce needs and expertise that are crucial for operations to succeed. At times, it may be necessary to consult with or hire experts from other regions to develop and implement the environmental monitoring or operational aspects of the farm.

Before beginning operation, farm owners are encouraged to identify potential or perceived conflicts with the local wild harvest market, tourism, recreational users, aesthetics, cultural activities, or navigation. This is part of the community consultation and public review process. The community cultural setting should be compatible with the aquaculture venture; it should complement the community identity and not detract from it. Consider an alliance with the local fisher associations and highlight mutual goals. Of course, legal and insurance consequences need to be addressed. Potential conflicts with maritime traffic — recreational and commercial — need to be identified and measures put in place to avoid them.

From the initiation of a new project, the farm operation should strive to develop a good neighbor policy. Refer to the *Code of Conduct for Responsible Aquaculture* (Appendix 1) as a straightforward message for the community about common sense guidelines for responsible aquaculture management practices within the larger seafood producing community.

To foster community support for long-term mutual benefit, include such strategies as offering student internships and scholarships, purchasing equipment and supplies from local merchants, and supporting local community initiatives. Once local human resources are identified and employed, the company must provide safe and clean working conditions. Provide the work force with safety training, meet or exceed the local wage and provide benefits for workers. Help the community with infrastructure needs, if possible. This could include supporting efforts to maintain high health standards for local waters, providing internet access for students, facilitating local transportation, or providing lodging options.

Market the cultured fish within the local community when possible, especially if it is new to the local culture. If the industry is working in alliance with the local fisher associations, provide opportunities to promote and sell farmed fish to local restaurants or other buyers. New marketing techniques, including new recipes or uses for the product, can be tested in local communities. Complement existing markets with new products when possible. The production of a variety of seafood products can provide market stability. The byproducts of the main culture species may even result in spinoff businesses or creation of associated cottage industries. This helps to diversify the local economy and integrate the farm operation into the community. Because marine aquaculture is a relatively new endeavor, fish farmers need to support each other.

To further gain public support for aquaculture, follow humane harvest guidelines. Refer to the methods suggested by the Humane Slaughter Association (www.hsa.org.uk) and the Humane Society of the United States (www.humanesociety.org), which include percussive stunning, electrical stunning, carbon dioxide narcosis, live chilling, and ice slurry immersion. Processing should be done in compliance with the Hazards Analysis Critical Control Point (HACCP) plan as required by the U.S. Food and Drug Administration (www.fda.gov).

Farmed seafood products should comply with labeling requirements as established by country of origin labeling (COOL) regulations of the USDA Agricultural Marketing Service. This means that everything from wild caught fish to bagged frozen shrimp must, by law, carry a label stating where it was caught, where it was processed, and whether it was caught in the wild or farmed. These regulations have been in effect since 2005.

Best Management Practices for Human Dimensions

1. Conduct outreach to the local community to educate them about the marine aquaculture industry,
2. Conduct public hearings or input process prior to permit as required,
3. Conduct economic/market analysis to project local economic effects,
4. Identify potential or perceived conflicts with wild harvest market, tourism, recreational use, aesthetic value, cultural activities, or navigation,
5. Develop a Good Neighbor Policy,
6. Employ and train local workforce when possible,
7. Meet or exceed local wage and benefits requirements for workers, provide safety training, and ensure safe and clean working conditions,
8. Work with the local community to market cultured fish when possible,
9. Complement existing markets with new products when possible,
10. Follow humane harvest guidelines, and
11. Comply with processing, labeling and seafood safety requirements.

7. PERMITTING

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Multiple permits are required to secure a site and operate a marine cage culture operation in the U.S. Caribbean. Applicants should proactively contact the appropriate local, state, and federal agencies prior to beginning the application process and maintain regular communication with regulatory agencies and provide information on a timely basis to reduce permitting delays. Sufficient information should be provided to regulatory agency staff regarding the specifics of the operation, and any changes to the proposed farm should be reported to the appropriate regulatory agencies. This chapter provides a list of the regulatory agencies involved in permitting marine cage culture operations in the U.S. Caribbean, and a brief description of each agency's jurisdiction and responsibility. Contact information for each agency is provided in Appendix II.

Territorial Regulatory Agencies

Permitting requirements will vary depending upon whether the facility is to be sited in Puerto Rico or the U.S. Virgin Islands (USVI) waters. The lead agency for permitting in Puerto Rico is the Department of Natural and Environmental Resources (DNER), while the Department of Planning and Natural Resources (DPNR) is the lead agency in the USVI.

Puerto Rico

Puerto Rico's territorial waters extend nine nautical miles from the coast. Aquaculture activities within this area require a Federal and Commonwealth Joint Permit Application for Water Resource Alterations in Waters, including Wetlands of Puerto Rico (i.e., Joint Permit Application*)*. The Joint Permit Application provides a consolidated process to request relevant permits from the Puerto Rico DNER, U.S. Army Corps of Engineers (USACE), the Puerto Rico Planning Board (PRPB) and the Environmental Quality Board (EQB) for the use of water resources within the jurisdictional waters of the U.S. and Puerto Rico. The Joint Permit Application may be obtained at and submitted to DNER. A proponent agency is required to submit and process the Joint Permit Application. The *Consejo de Arqueologia Subacuatica* (Underwater Archaeology Council), the Puerto Rico State Historic Preservation Office (SHPO) and the Ports Authority must also be consulted to endorse the proposed project if no conflicts are determined.

Any federally funded project, federal agency project, or any project requiring a federal permit or license located within the Puerto Rico Coastal Zone or that may have direct or indirect impacts on coastal or marine resources will require a Coastal Zone Federal Consistency Certification. In addition, the capture, importation and exportation of aquaculture organisms is regulated in Puerto Rico under Fisheries Law 278 of November 29, 1998 and Fisheries Regulation #7949 and requires a special permit from the Secretary of DNER[1].

In cases where the DNER considers it necessary (e.g., concession of submerged land), a public responsibility insurance policy and/or an Environmental Impact Statement may be required for the activity, in compliance with Law 416 of September 22, 2004, known as the Environmental Public Policy Law.

U.S. Virgin Islands

The territorial waters of the USVI extend three nautical miles from the coast. Aquaculture activities within this area require a Joint Permit Application with DPNR, USACE and the U.S. Environmental Protection Agency (EPA). All three islands are considered to be within the coastal zone as defined by the Virgin Islands Coastal Zone Act of 1978, so any land or water development in the coastal zone also requires a Virgin Islands Coastal Zone Management Program (VICZMP) permit which may grant a concession to lease submerged land for a period of 20 years (in increments of five years).

The USVI Legislative Act 6471 of November 2001 as amended by Act 7101 section 11 of September 2009 established a Virgin Islands Commission on Aquaculture

[1]Puerto Rico DNER is currently working on a new Fisheries Law. Please check with the DNER for the latest version.

and Mariculture (Commission) within the Department of Agriculture which developed a Five-year Aquaculture Plan. However, the lack of a Commission is currently hampering efforts to move forward. In December 2011, the USVI Legislative Act 7333, the 'Farmer's, Fishermen and Consumer's Assistance Act' was passed by the Twenty-Ninth Legislature. This Act includes a provision which exempts farmers and fishermen from certain taxes levied by the USVI to encourage industry growth.

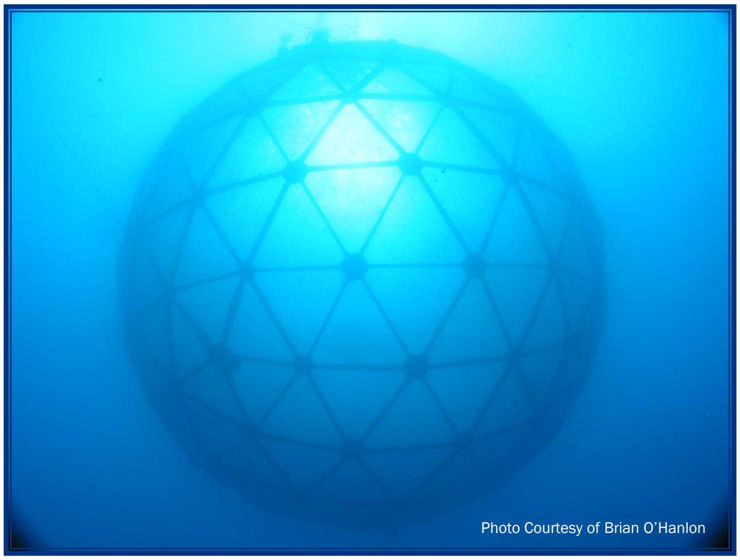
Photo Courtesy of Brian O'Hanlon

Federal Regulatory Agencies

Several federal agencies are involved in permitting marine aquaculture operations, including the USACE, EPA, and NOAA Fisheries Service. Other federal permits may also be required depending on the type, size and location of the proposed facility.

U.S. Army Corps of Engineers

The Rivers and Harbors Act of 1899, Section 10 (33 U.S.C. 403) establishes permit requirements to prevent unauthorized obstruction or alteration of navigable waters of the United States. The Section 10 permitting process assesses the environmental effects of a structure and its operations, including effects on navigable waters of the U.S., and each marine cage culture operation must secure a Section 10 permit. During the permitting process, the USACE will consult with the NOAA Fisheries Service, which may provide recommendations to avoid impacts to endangered species, essential fish habitat, or other marine resources.

U.S. Environmental Protection Agency

Under Section 402 of the Clean Water Act (i.e., CWA, Federal Water Pollution Control Act), the EPA may require point source pollution discharge permits via the National Pollutant Discharge Elimination System (NPDES) program. These NPDES permits regulate "concentrated aquatic animal production" (CAAP) facilities including fish culture operations, hatcheries, and other aquaculture operations in marine waters.

An NPDES permit is required for CAAP facilities that either:

i) Produce more than 20,000 pounds of cold water fish, or
ii) Produce more than 100,000 pounds of warm water fish per year.

In 2004 (69 F.R. 162), the EPA published a final rule which established effluent limitations, guidelines and new point source pollution standards for CAAP facilities under the CWA.

NOAA

NOAA offices may issue permits authorizing aquaculture activities under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) and the National Marine Sanctuaries Act (NMSA).

NOAA consults with other federal agencies that issue permits for aquaculture activities in state and federal waters. Most frequently, NOAA consults with the USACE as most finfish and shellfish aquaculture facilities in state or federal waters require a federal permit from this agency. Consultations focus on impacts of aquaculture on Endangered Species Act (ESA) listed species, critical habitat for ESA- listed species, and essential fish habitat (EFH) for MSFCMA-managed species.

U.S. Coast Guard

The U.S. Coast Guard (USCG) regulates various activities in navigable waters of the U.S. and requires that structures be marked with lights and signals to ensure compliance with private aids to navigation (Title 33 C.F.R. 66.01), as well as the marking of structures, sunken vessels and other obstructions for the protection of maritime navigation (Title 33 C.F.R. 64). For marine cage culture operations, this may mean requiring lights or signals on cages and other equipment or structures at sea.

U.S. Fish and Wildlife Service

Under the authority of the Fish and Wildlife Coordination Act (Title 16 USC 661) the U.S. Fish and Wildlife Service may review activities that are authorized, permitted or funded by the federal government and make recommendations to the responsible agencies regarding the interests of fish, wildlife, and their habitats. The agency also has regulatory responsibilities under the ESA, Marine Mammal Protection Act and the Migratory Bird Treaty Act. Section 7 consultations for manatees and coastal plants may be required depending upon the location of aquaculture operations.

Other Federal Considerations

For a proposed marine cage culture operation, an environmental review is required under the National Environmental Policy Act (NEPA) to analyze environmental effects of the project and activities. Typically, the lead federal agency for the NEPA process is the agency which first receives a permit application. In some cases, it could also be the federal agency that is funding the project.

The Coastal Zone Management Act (CZMA) is administered by NOAA's Office of Ocean and Coastal Resource Management and implemented through state coastal zone management programs. The CZMA requires that an applicant for a federal license or permit for an activity affecting the coastal zone provide a certification to the authorizing agency that the proposed activity complies with the enforceable policies of approved state coastal zone management programs and that such activity will be conducted in a manner consistent with the program.

Marine cage culture operations must also comply with federal rules, monitoring, and reporting requirements concerning aquatic health per the USDA Animal Plant Health Inspection Service, and the use of chemicals and drugs as regulated by the EPA and Food and Drug Administration, respectively.

Best Management Practices for the Permitting Process

1. Consult with regulatory agencies prior to applying for permits,
2. Maintain communication with regulatory agencies during the permitting process,
3. Provide information on a timely basis to regulatory agencies,
4. Take steps to educate regulatory agency staff on aquaculture operations, as appropriate,
5. Work with the lead federal agency to facilitate timely NEPA analysis,
6. Comply with all local, territorial and federal regulations,
7. Report any proposed changes to the appropriate agencies in a timely manner, and
8. Work with regulatory agencies to develop a streamlined permitting process.

8. SITING

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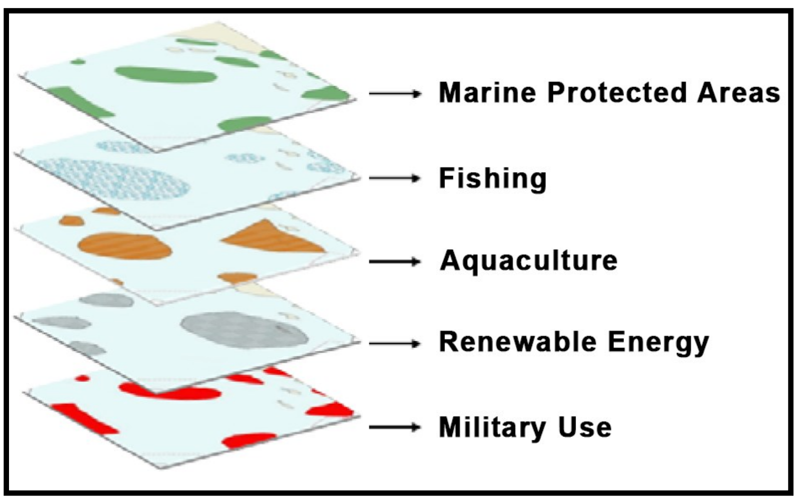
Site selection is one of the most important variables to consider early in the establishment of a new marine cage culture operation. Because marine farms are located in ocean areas that are public domain, many factors must be considered when selecting the optimal site. To determine the site of a fish farm near-shore or offshore using floating or submerged cage systems, a site assessment must be conducted to evaluate parameters related to infrastructure, topography, bathymetry, meteorology, annual ranges of water quality parameters and environmental and biological information, and the local, territorial, state, and federal regulatory frameworks.

When evaluating a site, among the foremost aspects to consider is the infrastructure that will be needed to support operational logistics. Accessibility to main roads, transportation, ports, airports, power lines, fuel sources, along with docking and air cargo freight facilities, are all important. The telecommunications and postal delivery infrastructure is also essential. Reliable access to freshwater and other public utilities must be available at all land-based facilities supporting the operation.



The site selection process usually starts with the identification of a larger general area that is potentially suitable. The best way to begin is to look at maps, charts, satellite images and aerial photos such as those available at Google Earth™ mapping service. These data may be analyzed with the use of Geographic Information Systems (GIS) which facilitate the identification of user conflicts by overlaying maps of the activities or jurisdictions of various stakeholders on potential farm locations. This methodology is especially useful when attempting to avoid user conflicts and eliminate harmful interaction with the native biodiversity, critical habitats such as Marine Protected Areas, navigation routes, military boundaries, recreationally important areas, or natural resource extraction operations (oil rigs). Once conflict areas are eliminated from siting consideration, the most appropriate site is selected, and *in situ* detailed assessments must be conducted to characterize it (see the Monitoring and Reporting section). It is important that the selected site have water currents that provide adequate flushing rates and that it is away from sensitive ecosystems such as coral reefs. An example of a checklist to help organize the importance of each factor in a matrix is provided (Table 1).

Once operational, a marine fish farm will often depend on a land-based facility for its hatchery supply of fingerlings, thus specific information will be required for both on-land and coastal or offshore grow-out facilities that will provide and rear fingerling stock. Thus, it is important to consider water quality and quantity, seasonal variations in the water quality parameters such as temperature, dissolved oxygen, salinity and turbidity, and tidal ranges under normal and storm conditions for the shore-based support facility. For the offshore site, water current patterns must be known in detail. Because fish growth rate is correlated to water temperature, the seasonal variation of water temperature needs be precisely monitored to correctly estimate production biomass.

Depending on regulatory agencies guidance and the type of cages selected for grow-out, the need for boundary markers (usually buoys with or without signs or lights) might be required. If required, this will add another task level of maintenance and logistic to consider as part of the overall operation and budget.

Best Management Practices for Siting

1. Site facilities in areas with sufficient flushing rates,
2. Avoid siting in areas that may impact sensitive ecosystems (e.g., coral reefs),
3. Use siting to decrease interaction with native biodiversity and critical habitats such as Marine Protected Areas,
4. Identify local and regional infrastructure required to support marine operations, and
5. Install farm boundary markers and signs

Table 1. Check list for site assessment criteria for open ocean cage aquaculture. Adapted with permission from: Benetti, D.D., G.I. Benetti, J.A. Rivera, B. Sardenberg, and B. O'Hanlon, 2010. Site Selection Criteria for Open Ocean Aquaculture. *Marine Technology Society Journal* **44**(3):22-35.

	YES	NO	IN PROGRESS	NOTES
GIS, Google Earth, satellite images				
Maps, hydrographic/navigational charts				
Areas of conflicting use (identify / eliminate)				
Tentative site selected				
Legal framework (local, state, country)				
Acceptance of project by local government/public				
Manpower available at all levels				
Subcontractors for key services (net cleaning, diving)				
Logistics & infrastructure				
Accessibility - roads, dock, entertainment, etc.				
Land-based facilities (comfortable housing for staff)				
Communications (telephone, computers, etc.)				
Electricity				
Freshwater				
Proximity to processing plant, airport, port				
Environmental baseline/assessment/monitoring				
Bioremediation, mitigation needs				
Depth profile; bathymetry				
Distance from shore				
Bottom type				
Exposure to wind; fetch				
Current velocity (desirable range from 0.2 to 1.5 knots)				
Maximum wave height (swell) (>3m)				
Tides (related to coastal-driven tidal currents)				
Water quality				
River runoff /stratification layers (seasonal)				
Plankton occurrence and distribution				
Red tides, plankton blooms				
Predators - sharks, birds, seals, etc.				
Potential for expansion – available adjacent area				
Market, technology, business & economics				
Understand commitment, investment, time required				

9. ENVIRONMENTAL MONITORING, RECORDKEEPING, AND REPORTING

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NOAA National Ocean Service and NOAA National Marine Fisheries Service

Marine cage culture operations need diligent monitoring, recordkeeping, and reporting to operate in harmony with local communities, neighboring operations, and the environment. To garner broad-based support from stakeholders, operations must exhibit regard for environmental protection and minimize adverse environmental impacts whenever possible. While operations can benefit from open dialogue with industry experts, scientists, and regulatory agencies, engaging affected communities and the public can also help to mitigate environmental impacts through cooperative development of innovative solutions and strategies.

Monitoring protocols are generally established before an aquaculture permit is issued by a regulatory agency. Typically, these protocols outline who conducts the sampling, which environmental parameters must be sampled, and the sampling frequency and methodology. In many cases, monitoring programs allow for flexibility, as long as the approach is justified in a valid systematic sampling design and appropriate quality assurance and quality control (QA/QC) are identified. A successful, well-executed monitoring program that meets its objectives can be invaluable for production planning, conducting economic analyses, justifying business expansion, or locating future projects.

Monitoring programs should take into account both the location and size of the operation, as well as potential environmental effects. When creating a sampling program, the entire site area should be considered, and reference sites should be included in order to detect both long-term and far field impacts. Sampling stations should also be selected with regard to local bathymetric and hydrodynamic conditions, information on local contamination sources, and knowledge of previous environmental surveys, if available. For each cage array, sampling stations should be positioned along a transect aligning with prevailing currents to include the downstream area of influence. Sampling stations along each transect should be established at the center of each cage array, at the edge of each cage array, and at stations positioned at regular distances from the edge of each cage array. For comparison, stations at reference sites should be representative of the regional ecosystem with bathymetric, hydrographic, and sediment profiles similar to the aquaculture site.

Monitoring should be conducted on farm sites during all phases of development, including prior to installation (i.e., baseline assessment). The baseline assessment should include the same sampling parameters as the long-term monitoring program, but may also include a detailed base map, hydrographic study, and computer simulation of water column and benthic impacts. Both the baseline assessment and long-term monitoring should include video-recorded observations of benthic substrates, hydrographic information, water quality measurements, sediment analysis, and benthic community assessment. Sampling and data collection should occur at intervals that capture seasonal variation in circulation, water quality, and other environmental characteristics. Sites that exhibit a range of natural variability will require frequent sampling for comparison of environmental effects relative to background conditions.

Regulation of the marine aquaculture industry should strive to minimize impacts to water quality and disruption to the surrounding marine ecosystem. It is important to understand which nutrients are derived from offshore aquaculture operations and how these nutrients impact the surrounding environment. Natural variability in ocean, nutrient, hydrographic, and climatic conditions might mask or affect the positive results of an operation's BMP implementation. Assistance in understanding these processes is available through agency resource specialists, consultants, and local universities.

A common approach to detect environmental impacts is to directly monitor farm discharge. It may also be necessary to monitor secondary parameters critical for interpretation of results. For example, measurement of total ammonia nitrogen requires measurement of temperature and pH to calculate ammonia toxicity. If direct monitoring is expensive or difficult, a viable alternative could include monitoring response variables (e.g., measuring the amount of chlorophyll in a sample rather than measuring nutrient concentrations directly). This type of sampling will ensure that the variables being measured are correlated with changes in the nutrients of concern.

Computer simulation models offer an approach to understanding how discharge disperses around fish farms and the potential effects of this discharge on the surrounding marine ecosystem. Information from these models can be used to guide the siting process for marine aquaculture operations and can also be integrated into geographic information systems (GISs). Coupling an environmental impact model with GIS provides data visualization and a realistic expectation of what may occur at an aquaculture site under different operational regimes or production scales. It is critical that the strengths and limitations of any model are well understood and that models are calibrated and validated for local conditions. Modeling is useful for development of offshore aquaculture operations, but managers may need outside expertise to make informed decisions about the cost, complexity, and time required for development of a model and acquisition of data.

This section does not provide detailed descriptions of analytical techniques or procedures for monitoring offshore aquaculture operations. However, other commercial operations, laboratories, consulting firms, and regulatory agencies have established standard operating procedures and protocols for sample collection, handling, processing, and data reporting. It is important to note that regulatory agencies will not accept monitoring data unless the methods of data collection, storage, and analysis are well documented. Operational managers should consider developing a Quality Assurance Project Plan (QAPP) to ensure that procedures for monitoring and reporting will meet all regulatory requirements.

Keeping accurate, organized records will help inform management decisions and make onsite inspections go smoothly. Poorly recorded, disorderly, or lost data represent an enormous and often irretrievable loss in information, time, and money. Environmental monitoring data, fish inventory, feeding, chemical use, and health management should be summarized in periodic reports. It is also important to maintain paper copies of records and backup all pertinent electronic information. Some farms may even choose to implement a security system to prevent unauthorized access to records and limit the ability of authorized individuals to access data. In general, records should be kept for at least three years and be readily available when requested by any regulatory agency.

Some offshore aquaculture operations use affiliations with trade associations to perform audits and certify farm practices as environmentally and socially responsible. To preserve the independence of the audit function, regulatory agencies should not routinely request audit reports. Audits should be independent of routine monitoring or quality control functions, and should evaluate compliance with standard operational protocols, BMPs, and applicable regulatory requirements. However, farms should provide evidence of audits or certificates when legally required.

An aquaculture permit should clearly define the frequency, format, content, and distribution of monitoring reports and identify which agency shall review the reports. Reports should include records of actions taken or recommendations to secure compliance. Farm managers are responsible for making sure that the regulatory agencies are aware of any changes in culture practices or operational procedures. Such changes may require additional documentation and supplemental reporting. A copy of all correspondence with the regulatory agencies should be kept for reference. Regulatory agencies should also take steps to safeguard proprietary business information in all submitted reports.

Best Management Practices for Environmental Monitoring, Recordkeeping and Reporting

1. Develop a Quality Assurance Project Plan for monitoring, recordkeeping, and reporting,,
2. Conduct an environmental baseline assessment and establish reference sites for long-term monitoring,
3. Conduct *a priori* sediment mapping of lease sites,
4. Follow federal and state agency protocols required for water quality and benthic monitoring,
5. Utilize modeling approaches to predict dispersion and benthic impacts, when possible,
6. Conduct routine surveys and keep records of marine debris generated by the operation,
7. Develop standard practices for aquatic animal health monitoring, management, and reporting,
8. Report impacts to wildlife through escapement, entanglement, and other interactions to regulatory agencies in a timely manner,
9. Monitor any environmental response to implementation of BMPs to ensure that the anticipated outcomes are achieved, and
10. Communicate with stakeholders and provide information on environmental initiatives to the public through websites and other media outlets.

Best Management Practices for Marine Cage Culture Operations in the U.S. Caribbean

1. Best Management Practices for Ecological Effects

1.1 Optimize feeding protocols,
1.2 Minimize nutrient accumulation at the site,
1.3 Implement cage rotation or fallowing if nutrient loading exceeds ecological threshold,
1.4 Avoid disruption to native biodiversity, especially protected species,
1.5 Prevent predator interactions and use non-lethal predator deterrents, when necessary,
1.6 Employ methods to minimize physical disturbance to habitat,
1.7 Utilize responsible cage cleaning methods,
1.8 Use proper cage design to minimize entanglement with marine animals and other protected species,
1.9 Site farms away from corals, seagrass, mangroves, and other sensitive habitats, and
1.10 Exercise caution when operating vessels to avoid collisions with sea turtles and marine mammals.

2. Best Management Practices for Water Quality

2.1 Establish nutrient and water quality thresholds,
2.2 Tailor monitoring plan(s) to take into account impacts to sensitive marine habitats,
2.3 Consider the use of integrated multi-trophic aquaculture systems, when practicable,
2.4 Discourage the use of chemical antifoulants and employ mechanical cleaning methods, when possible,
2.5 Quickly remove and properly dispose of fish mortalities,
2.6 Encourage clean harvest methods and off-site processing,
2.7 Collect operational and human waste for off-site disposal,
2.8 Take measures to prevent discharge of contaminants from farm and develop a chemical spill response plan,
2.9 Properly maintain and operate farm vessels and equipment to minimize leaks, spills or, waste loss, and
2.10 Provide employees with approved marine sanitation devices aboard vessels or working platforms.

3. Best Management Practices for Escapes

3.1 Develop and regularly update an escapes reduction and mitigation plan for each farm,
3.2 Use cage designs which minimize the possibility of escape,
3.3 Routinely monitor cages for escapement and properly maintain cage equipment,
3.4 Take measures to avoid unintended releases of cultured gametes, eggs, and larvae,
3.5 Culture local (native or naturalized) species and discourage or prohibit the culture of non-native species,
3.6 Require risk assessment for non-local species,
3.7 Develop a broodstock program that conserves genetic diversity (integrated approach) or selects for low wild fitness (segregated approach), and
3.8 Consider stocking sterile fish, when practicable.

4. Best Management Practices for Fish Health

4.1 Develop a health monitoring plan and protocols,
4.2 Consult with an aquatic animal health expert or veterinarian at various levels of operation,
4.3 Develop and employ biosecurity practices and quarantine protocols,
4..4 Use appropriate stocking densities and employ techniques to minimize physiological stress to cultured organisms,
4.5 Vaccinate fish prior to stocking into cages, if available and necessary,
4.6 Use only FDA-approved drugs,
4.7 Minimize the use of antimicrobials,
4.8 Cooperate with animal health regulators, and
4.9 Coordinate with veterinary, husbandry, and fish pathology researchers, when possible.

5. Best Management Practices for Feeds

5.1 Minimize use of raw or unprocessed feeds,
5.2 Promote techniques to improve feed conversion ratio and minimize excess feed input,
5.3 Maintain and analyze records of fish growth, survival, feed used, feeding times and amounts,
5.4 Provide feed company with desired composition, performance and practical feeding requirements (sinking rate, fines, pellet hardness, etc.) for each cultured species and work with them to improve in these area,
5.5 Encourage feed companies to use feedstuffs from environmentally responsible sources and practice continuous improvement in all aspects of feed formulation and manufacture,
5.6 Procure feed with an adequate amount of long chain omega-3 fatty acids (EPA and DHA) to produce a final product with equal or greater levels of these fatty acids compared to that of the same species from the wild,
5.7 Procure feed with minimal toxins of concern for human health and monitor for key toxins in the product, and
5.8 Handle and store food appropriately to maintain quality.

6. Best Management Practices for Human Dimensions

6.1 Conduct outreach to the local community to educate them about the marine aquaculture industry,
6.2 Conduct public hearings or input process prior to permit as required,
6.3 Conduct economic/market analysis to project local economic effects,
6.4 Identify potential or perceived conflicts with wild harvest market, tourism, recreational use, aesthetic value, cultural activities, or navigation,
6.5 Develop a Good Neighbor Policy,
6.6 Employ and train local workforce when possible,
6.7 Meet or exceed local wage and benefits requirements for workers, provide safety training, and ensure safe and clean working conditions,
6.8 Work with the local community to market cultured fish,
6.9 Complement existing markets with new products when possible,
6.10 Follow humane harvest guidelines, and
6.11 Comply with processing, labeling and seafood safety requirements.

7. Best Management Practices for the Permitting Process

7.1 Consult with regulatory agencies prior to applying for permits,
7.2 Maintain communication with regulatory agencies during the permitting process,
7.3 Provide information on a timely basis to regulatory agencies,
7.4 Take steps to educate regulatory agency staff on aquaculture operations, as appropriate,
7.5 Work with the lead federal agency to facilitate timely NEPA analysis,
7.6 Comply with all local, territorial, and federal regulations,
7.7 Report any proposed changes to the appropriate agencies in a timely manner, and
7.8 Work with regulatory agencies to develop a streamlined permitting process.

8. Best Management Practices for Siting

8.1 Site facilities in areas with sufficient flushing rates,
8.2 Avoid siting in areas that may impact sensitive ecosystems (e.g., coral reefs),
8.3 Use siting to decrease interaction with native biodiversity and critical habitats such as Marine Protected Areas,
8.4 Identify local and regional infrastructure required to support marine operations, and
8.5 Install farm boundary markers and signs.

9. Best Management Practices for Environmental Monitoring, Recordkeeping and Reporting

9.1 Develop a Quality Assurance Project Plan for monitoring, recordkeeping, and reporting,
9.2 Conduct an environmental baseline assessment and establish reference sites for long-term monitoring,
9.3 Conduct *a priori* sediment mapping of lease sites,
9.4 Follow federal and state agency protocols required for water quality and benthic monitoring,
9.5 Utilize modeling approaches to predict dispersion and benthic impacts, when possible,
9.6 Conduct routine surveys keep records of marine debris generated by the operation,
9.7 Develop standard practices for aquatic animal health monitoring, management, and reporting,
9.8 Report impacts to wildlife through escapement, entanglement, and other interactions to regulatory agencies in a timely manner,
9.9 Monitor any environmental response to implementation of BMPs to ensure that the anticipated outcomes are achieved, and
9.10 Communicate with stakeholders and provide information on environmental initiatives to the public through websites and other media outlets.

APPENDIX 1

CODE OF CONDUCT FOR RESPONSIBLE AQUACULTURE

This Code of Conduct is a voluntary set of principles to encourage marine cage culture practices for an industry that is economically profitable as well as environmentally and socially responsible. The following common sense guidelines promote active participation of farmers in the development and implementation of responsible aquaculture management practices within the larger seafood producing community.

1. **Farms should be permitted properly and operations conducted in compliance with all federal, state, and local regulations. Proactive planning should include siting farms in deep, well-flushed water.**

2. **Farmed seafood products should be safe and of high quality.**

3. **Establish good business and community relationships with neighbors, both on land and at sea. When possible use local work force and infrastructure to support farm operations.**

4. **Take steps to minimize harmful environmental impacts. Monitoring plans should be in place for early detection of impacts. Adaptive management plans will be useful for early interventions and response.**

5. **Follow husbandry practices that promote good fish health and avoid stress and disease. Report any outbreaks immediately to proper authorities.**

6. **Dispose of all farm harvesting waste, chemicals, and debris in a responsible manner to avoid harm to human health or the environment.**

APPENDIX 2

State and Federal Agency Information for the U.S. Caribbean

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The **Puerto Rico Department of Natural and Environmental Resources (DNER)** and the **Environmental Quality Board (EQB)** are located in the Dr. Cruz Matos Environmental Agencies Building, Sector el 5, Hwy. 8838, Km. 6.3 Rio Piedras, PR 00926. The Puerto Rico Planning Board is located in the Roberto Sánchez Vilella Government Center, Santurce, Puerto Rico 00940.

The **USVI Department of Planning and Natural Resources (DPNR)** has two locations. The St. Thomas Office is located at 6291 Estate Nazareth, St. Thomas, VI 00802. The St. Croix Office is located at 45 Mars Hill Complex, St. Croix, VI 00840.

The **U.S. Army Corps of Engineers (USACE)** Antilles Office administers construction projects throughout the island of Puerto Rico and the USVI. The address for the Antilles office is 400 Fernandez Juncos Avenue, Puerta de Tierra, San Juan, PR 00901-3299.

The **U.S. Environmental Protection Agency** (**EPA)** Region 2 office in New York, New York services Puerto Rico and the USVI in addition to New Jersey, New York, and eight tribal nations. The EPA also maintains a Puerto Rico office at City View Plaza II Building, 7th Floor, State Rd 165, Guaynabo, PR 00968 and a USVI office at Tunick Building, Suite 102, 1336 Beltjen Road, St. Thomas, VI 00801.

NOAA Fisheries' Southeast Regional Office is located at 263 13th Avenue South, St. Petersburg, Florida. This office oversees issues in the U.S. Caribbean, as well as the Gulf of Mexico, and South Atlantic. The Puerto Rico office location for the Habitat Conservation Division for essential fish habitat consultations is co-located with the USACE office at 400 Fernandez Juncos Avenue in Puerta de Tierra, San Juan. The Protected Resources Division location for Endangered Species Act Section 7 consultations is co-located with the U.S. Fish and Wildlife Service, Cabo Rojo National Wildlife Refuge at State Road # 301, km 5.1, Cabo Rojo, PR 00623.

APPENDIX 3

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APPENDIX 4

Best Management Practices in the U.S. Caribbean Workshop Summary

63rd Gulf and Caribbean Fisheries Institute

San Juan Puerto Rico November 2 - 3, 2010

Workshop for Development of Sustainable Practices for Marine Cage Culture Operations in the U.S. Caribbean

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ABSTRACT

On November 2nd and 3rd, 2010 the NOAA Aquaculture Program and NOAA Coral Reef Conservation Program, in cooperation with Puerto Rico Sea Grant and the Gulf and Caribbean Fisheries Institute (GCFI), hosted the *Workshop for Development of Sustainable Practices for Marine Cage Culture Operations in the U.S. Caribbean*. This one and a half day invited workshop was convened in conjunction with the 2010 GCFI annual meeting in San Juan, Puerto Rico. The purpose of the workshop was to facilitate exchange of scientific and regulatory information as a first step toward developing environmental guidelines for marine cage culture operations in the U.S. Caribbean. Discussions focused on exchanging scientific information and identifying areas of uncertainty and knowledge gaps for marine cage culture operations. Break-out sessions were held to identify key elements for regional Best Management Practices (BMPs) for marine cage culture operations in territorial waters of the U.S. Caribbean. A second workshop will be held to seek input from additional experts and continue development of the regional BMPs.

KEY WORDS: Marine cage culture; Best Management Practices; U.S. Caribbean

INTRODUCTION

With seafood demand on the rise and wild fisheries harvest reaching a plateau, there is strong interest in developing sustainable aquaculture around the world, including in the U.S. Caribbean region. Poorly sited and/or managed aquaculture operations in the U.S. Caribbean have the potential to negatively impact coral reef ecosystems. However, increased aquaculture production could supply local seafood, reduce pressure on reef species and provide economic opportunities for coastal communities. Use of appropriate technologies and management practices may support increased sustainable aquaculture production in the U.S. Caribbean that does not pose a risk to coral reefs and other sensitive ecosystems.

The purpose of this workshop was to examine a wide range of issues regarding marine cage culture operations in the U.S. Caribbean and begin developing Best Management Practices (BMPs) to address potential effects on coral reef ecosystems. The need to develop marine cage culture BMPs specific to coral reef ecosystems was initially highlighted in 1999 by the U.S. Coral Reef Task Force. The NOAA Coral Reef Conservation Program (CRCP) has partnered with the NOAA Aquaculture Program (AQC), as well as Puerto Rico Sea Grant and other local partners, to host a series of workshops aimed at developing formal guidelines for marine cage culture operations in U.S. territorial waters of the Caribbean. This document outlines the first of these workshops which was held during the 63rd Annual Gulf and Caribbean Fisheries Institute (GCFI) Meeting in San Juan, Puerto Rico.

WORKSHOP OBJECTIVES

The workshop was attended by 30 representatives from various federal and state agencies, academic and scientific institutions, and individuals with experience operating marine cage culture systems. Several panels were convened to discuss ecosystem impacts, permitting and regulatory processes, and other considerations. A break-out session was held to identify key elements for inclusion in the regional BMPs.

Three major objectives were identified for the workshop, including:

i) Exchange scientific information to assist in evaluating potential environmental effects of marine cage culture operations on coral reef ecosystems.
ii) Identify major knowledge gaps that may impede permitting processes for marine cage culture operations and discuss information requirements for permit review.
iii) Identify the key elements for development of regional BMPs for marine cage culture operations sited near coral reef ecosystems.

WORKSHOP ACTIVITIES

The workshop began with a brief overview of Puerto Rico's fisheries and aquaculture regulations and economic challenges and opportunities in the region. Information on the potential impacts of marine cage culture operations on coral reef ecosystems, major threats to the health and productivity of coral reef ecosystems (climate change, land-based sources of pollution, and fishing impacts) and the rising U.S. seafood import deficit was also provided.

The first session provided an overview of the status of U.S. marine cage culture operations. Due to continued rise in demand for seafood products, a plateau in landings from capture fisheries and increased land values, marine cage culture operations are becoming more prevalent on a global scale. In the U.S., permitting uncertainty is seen as a roadblock to expansion of the industry and the lack of full- scale demonstration projects make it difficult to validate simulation models which predict potential environmental impacts. Opportunities for expansion of the U.S. aquaculture industry include a growing market for domestic seafood, food security, a large coastline, a well-trained workforce, diversity of aquaculture products and services, and technological advancements.

A panel of industry and academic representatives was convened to discuss ecosystem impacts and insight into the permitting process. Two common themes emerged from this panel, including:

i) Lengthy and cumbersome regulations and lack of streamlined permitting processes preclude industry expansion in the U.S., and
ii) Marine cage culture demonstration projects are needed to generate real world data and validate environmental models.

A second panel consisting of representatives from state and federal regulatory agencies discussed agency mandates, regulatory roles, and information needs to facilitate review of applications for marine cage culture operations. Some panelists believed that there is a lack of scientific information in regards to the environmental impact of marine cage culture operations on coral reef ecosystems and that additional studies are needed. Other panelists indicated that data from aquaculture operations around the world provide evidence that properly sited and managed aquaculture operations can have minimal impact on the environment.

WORKSHOP OUTCOMES

Discussion Questions

Participants were asked to provide examples of major knowledge gaps that may impede the ability to properly evaluate and manage marine cage culture operations. In general, participants indicated that more information was needed in the following areas: potential impacts on coral reef ecosystems; substitutes for fish meal; competition with local fisheries; industry support/infrastructure; impacts of escapes; cultural conflicts; ecological carrying capacity; baseline study requirements; siting criteria; benthic impacts; and disease issues. There were also questions regarding how aquaculture fits into marine spatial planning efforts, which species are best suited for cage culture, and the cumulative/synergistic effects of marine cage culture operations.

Next, participants were asked to discuss various management strategies and areas of research which could help to address these knowledge gaps. Responses included: establish a demonstration project in the U.S. Caribbean; establish standardized monitoring protocols and require 3rd party monitoring; standardize *a priori* sampling designs; involve local stakeholders; provide permitting guidance; establish water quality standards and threshold nutrient levels; create aquaculture site maps and zoning plans; exchange information between agencies; and streamline the permitting process.

Break-out Groups

Participants were presented with a draft BMP list for marine cage culture operations and asked to provide feedback regarding how they would change or modify the list to best address concerns in the U.S. Caribbean. Key elements suggested by workshop participants are included in Table 1. No effort was made to prioritize the suggestions, and it is understood that further refinement and input from additional stakeholders is needed prior to finalizing the BMPs.

CONCLUSION

The objectives of this workshop were successfully met, and this was the first step toward developing BMPs for marine cage culture operations in the U.S. Caribbean. At least one more workshop will be held to further develop the regional BMPs, and there will be an opportunity for participants to provide their comments and feedback. More information on this workshop can be found at http://www.ccfhr.noaa.gov/research/marine_aquaculture.aspx.

ACKNOWLEDGEMENTS

The NOAA Aquaculture Program and NOAA Coral Reef Conservation Program would like to thank the GCFI for hosting and helping to organize this workshop. We would also like to thank all of the participants for their commitment of time and attention to the goals of the workshop. This initial workshop is the first in a series of invitational workshops funded in part by a National Fish and Wildlife Foundation grant (#10395- 2007), the NOAA Coral Reef Conservation Program and the NOAA Aquaculture Program.

***Appendix IV has been excerpted from its publication in: *Proceedings of the 63rd Gulf and Caribbean Fisheries Institute*. November 4—9, 2010, San Juan, Puerto Rico USA.**

Table 1. Suggested key elements for BMPs.

BMPs	Action strategies
Community Effects	Optimize feeding protocols Implement fallowing procedures Utilize non-lethal predator deterrents Develop comprehensive monitoring plan Establish permanent monitoring stations Develop protocols for dealing with recruitment of other species to cages (e.g., spiny lobsters) Define *a priori* thresholds for key coral ecosystem parameters Minimize physical disturbance to habitat Employ proper/responsible cage cleaning methods Utilize proper cage design(s) to minimize entanglement (e.g., with marine mammals) Require *a priori* sediment mapping of lease site and adjacent areas
Water Quality	Model projected nutrient loads Integrate regular water quality monitoring Remove and properly dispose of dead fish Develop standard monitoring protocols Employ real-time monitoring Conduct baseline survey for water quality conditions Use FDA/USDA approved drugs Establish local nutrient threshold levels Develop dispersion models for site Encourage use of integrated multi-trophic aquaculture Monitor nearby control site to assess changes in water quality Minimize use of anti-fouling chemicals/agents
Genetic Considerations	Require tag or genetic mark on stocked fish Utilize cage design(s) which minimize escapism Use native species Prohibit culture of non-native species Develop broodstock program to maintain genetic diversity Routinely monitor cages/pens for escapement Harvest stock prior to reproductive maturity Stock sterile fish Require risk assessment for non-local genetic strains or species

BMPs	Action strategies
Pathogens and Parasites	Minimize use of antibiotics Use FDA/USDA approved drugs Develop aggressive biosecurity practices Develop a pathogen and parasite monitoring plan Properly dispose of dead fish Use pathogen free broodstock and fingerlings Report incidence(s) of mortality to permitting agencies Use appropriate stocking densities Develop quarantine protocols Vaccinate fish prior to stocking into cages Monitor local pathology of wild species Attain fish health certification prior to stocking in cages Use fingerlings from a certified disease free facility
Feed	Encourage use of alternative feed sources and feeds from sustainable sources Develop efficient feeding protocols Document type of feed used and provide justification Optimize feed rate to reduce excess waste Use easily digestible feed Use feed with binders which reduce dust Monitor feeding events to maximize uptake rate of feed Utilize current regimes during feeding events Use feeds that are of the correct buoyancy to reduce sinking rates
Human Dimensions	Public input process prior to permit issuance Conduct economic/market analysis to project local economic effects Identify potential or perceived conflicts with wild harvest Provide educational materials and work on outreach issues with local community Hold informational meetings in local area Meet community needs when possible/practical (e.g., jobs) Train/employ local workforce when possible/practical Consider including tourism and recreational fishing in operations Avoid traditional fishing areas and areas of aesthetic importance Avoid flooding local market(s) with cultured fish Work with local community to market cultured fish when/where possible Complement existing markets with new products

BMPs	Action strategies
Permitting	Conform with all U.S. state, federal and territory environmental regulations Determine NEPA lead agency for permitting process Adapt existing EISs or EAs for new operations Provide permitting process guidelines Require initial consultation prior to beginning permitting process Provide access to permitting consultant Begin NEPA/Permitting process early in the planning stage Hold regular meetings with permitting agencies Educate permitting agency staff on aquaculture operations Educate industry to ensure compliance Streamline permitting process
Siting	Require baseline assessment Site facilities in areas with sufficient flushing rates Minimize interaction with wild aggregations, migrations, etc. Minimize interactions with critical habitat Develop siting maps for local and downstream environments Site in a manner to avoid/reduce user conflict(s) Develop plan to address storm impacts Conduct benthic surveys
Other	Consider culturing species with efficient food conversion rate Hold local workshop/training courses