Chapter 13
Offshore Platforms and Mariculture in the US

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Abstract Global demand for seafood is increasing. Supply from wild caught sources has been essentially flat for twenty years and, depending on the specific fishery, in decline for many species that are considered fully exploited or over-exploited. As the fastest growing sector of world food production, aquaculture is increasingly playing a major role and currently accounts for nearly half of the total aquatic production worldwide. Marine cage culture in particular provides an opportunity to utilize vast amounts of the world's surface area to produce fish, shellfish, and plants, while avoiding land-use conflicts in crowded coastal regions. Currently in the US, very small volumes of marine fish are produced and very large volumes are imported. This trend shows no signs of slowing down with an ever increasing annual seafood trade deficit. In an effort to initiate more domestic production, private companies, research institutions, and government agencies have all been involved in various types of aquaculture production. Aquaculture can be generally categorized as land-based, near shore, or offshore. Offshore marine fish culture utilizing cages has been conducted on both the east and west coast of the US as well as in the Gulf of Mexico (GoM). Specifics on the projects in the GoM are described in the following sections.

13.1 Background

The world's population is estimated to be approaching 9 billion people by 2050. UN estimates project the total global food supply will need to increase by 70% to keep up with demand and the growth of a larger and more urban population

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(FAO 2009). The world's oceans cover over 70% of the earth's surface and provide a large area to situate aquaculture operations that produce marine fish, shellfish, and plants. Currently, the ocean is underutilized as a location for protein production with 5% of the global protein supply (Oceanworld 2014) and a mere 2% of the total human calorie intake (UNEP 2012) acquired from this biome. Demand for food combined with a shortage of new arable land will require the global population to attempt to maximize production from the world's oceans. Potable freshwater and its distribution and use in the future is another critical reason to utilize the marine environment for aquaculture (Famiglietti 2014). All living organisms must have freshwater to live, including humans. The efficiency of rearing a million tons of protein in the marine environment when compared to producing the same amount of terrestrial protein becomes evident when the freshwater demand is considered. The current composition and location of water on the earth makes an obvious case for the use of the marine environment for aquaculture—that is where the water is! (Fig. 13.1).

The world is embracing aquaculture. Global output has increased from 7 million tons in 1980 to nearly 70 million tons currently and cultured product volume is projected to overtake capture fisheries within a few years. The US on the other hand, while being a major consumer of seafood products (ranked second behind

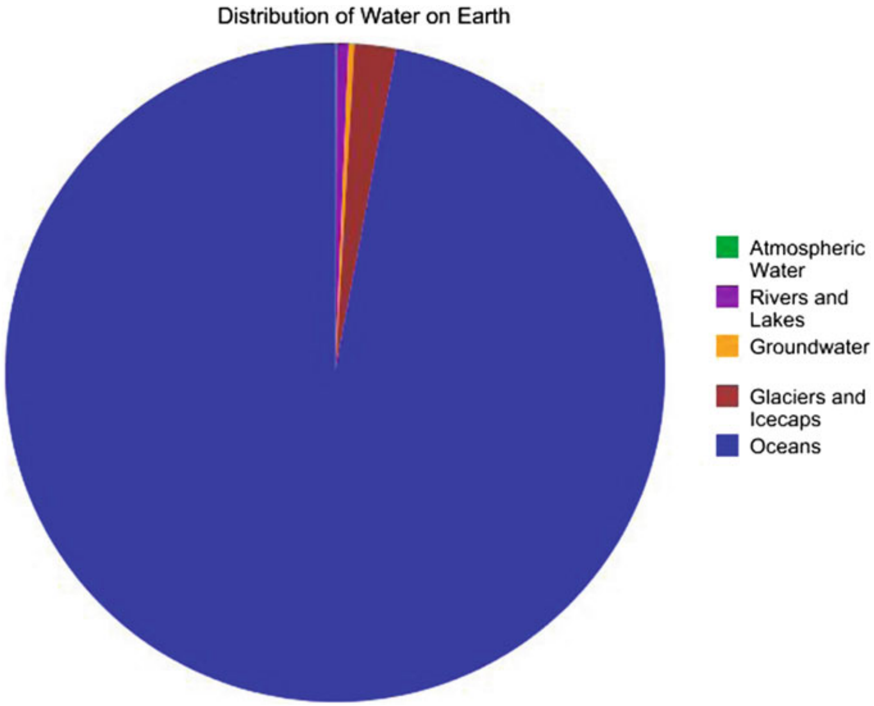

Fig. 13.1 Distribution of the earth's water (*Image* SanibelSeaschool.org)

China), is a minor producer of product and barely ranks in the top 15 producing countries (FAOFishStat 2016). The US currently imports around 90% of its edible seafood supply and has an annual trade deficit value of more than $10 billion—and that number is increasing each year. Ironically, for a country that has not effectively promoted domestic aquaculture expansion through easing of regulations and permitting processes, it is estimated that half of the product the US imports each year is produced by aquaculture (NOAA FishWatch.gov 2014).

Nearly half of the global population currently lives within 200 km of a coastline and that figure is expected to double by 2025 (PRB 2003). User conflicts and land demands for development will compete for space to conduct commercial scale marine aquaculture utilizing land-based pond or tank systems. Increasingly, both researchers and investors are considering the benefits of moving into the offshore environment where both water volume and water quality ameliorate many of the issues faced by traditional aquaculture production (Price and Morris 2013). While typically considered near shore, the explosion of the 1.8 million ton/yr salmon culture industry in the last 30 years is just one example of the potential rearing organisms in the marine environment offers. The vast majority of cage or net-pen operations currently in place are next to or within sight of land, which in most cases locates them within 10 miles of shore. Most, therefore, are situated with some sort of land mass nearby and are not exposed on all sides to prevailing wind and sea conditions.

With regards to the US coastline, several factors for siting of offshore aquaculture projects must be taken into consideration such as: distance from shore, water depth, logistics of maintaining personnel, feed, and equipment, transportation issues, environmental impact, culture species availability, product markets, among others. The GoM presents a unique situation because it is a sub-tropical saltwater environment which currently has nearly 3000 platforms in place associated with energy production. Certainly not all of these structures are in suitable locations for siting projects, but when the aforementioned factors are considered several of the existing platforms would be candidates for aquaculture. Supporting the energy industry are numerous vessels, terminal facilities, heavy equipment and experienced personnel, all of which would be valuable assets for the development of a commercial aquaculture venture in the offshore environment.

The mariculture projects utilizing offshore platforms described in the following sections were conducted in totally exposed locations and as such, presented the operators with unique challenges. Since 1990, there have only been three projects in GoM waters attempting to raise fish in cages either nearby or attached to oil and gas platforms. The platforms were used for monitoring the cage systems in addition to being a base of operation in two cases and strictly for observation purposes during the third project. It is important for the reader to note that the perspective offered by the co-authors is from direct personal experience working on two of these projects over several years—installing cage systems, stocking and feeding fish, inspecting and maintaining the cages, and living or working on the platforms involved. Results of these efforts will be discussed along with considerations for future use of oil and gas platforms for offshore aquaculture.

13.2 The Gulf of Mexico

Location is arguably the most important factor for any offshore cage culture project. Siting will dictate the expected sea conditions, type of cage system utilized, water parameters, and all transportation and logistical planning. These factors, among others, will ultimately determine the success or failure of a project. The GoM is characterized by short period wind driven waves for much of the year combined with tremendously powerful episodic tropical events during the June–November hurricane season. Offshore platforms, while engineered to withstand tremendous forces for decades, can be damaged or destroyed during hurricanes and tropical storms (Fig. 13.2) and an aquaculture project needs to have worst case contingency plans in place. Cage systems at totally exposed locations should be designed to survive a tropical event with nominal damage and above all, retain the fish within the system. Escaping the energy at the ocean surface is critical and submergible or submerged cages will likely be the preferred system in the GoM.

The distance the continental shelf extends into the GoM varies greatly depending on the specific location. It is the authors' assertion based on cage designs and diving requirements that for the purposes of siting, water depths of 30–60 + m would be considered adequate for offshore cage culture systems. This depth would allow for a cage to be submerged 10 m to escape the high energy surface forces and still have enough space for the cage volume and some allowance to maintain the system off of the bottom. The locations of the two projects off the coast of Texas, one 10 km

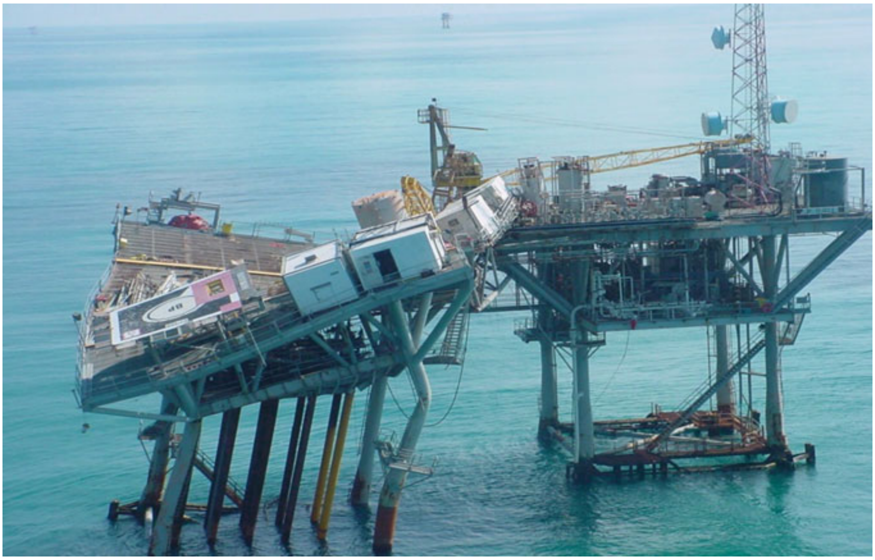

Fig. 13.2 Offshore platform damaged during a hurricane off of Louisiana

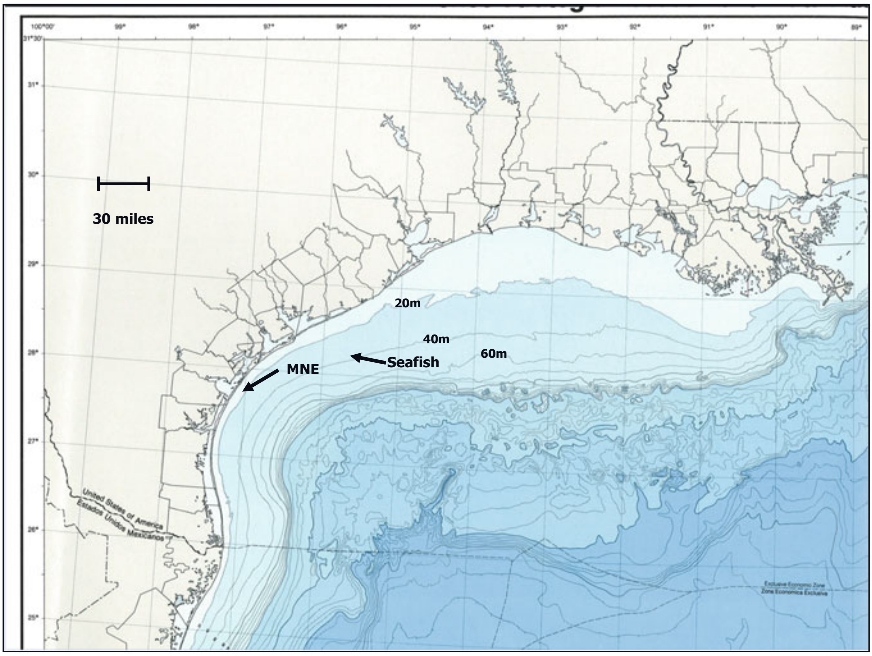

Fig. 13.3 Site locations for MNE Inc and Seafish aquaculture projects in the Gulf of Mexico

(21 m deep) and the other 42 km (40 m deep) offshore, are designated in Fig. 13.3. Conditions during these particular projects were seas calm to 7+ m, winds calm to above hurricane strength (78 knots and then the anemometer disappeared), and currents 0 to an estimated 130 cm/sec or 2.5 knots. During the course of several years, the weather pattern observed from worst to best conditions during seasons was periodic tropical events, followed by spring, winter, fall and summer. The period from February to May is particularly damaging to cage systems since the wind velocity and subsequent sea state often prevent site visits for maintenance from several days to as much as 2 weeks.

Wave action, currents, and fouling of net or cage materials will constantly wear and ultimately test all the materials of any offshore aquaculture system. Since weather and sea state determines when components can be safely inspected and repaired, the chosen design must assume extended maintenance intervals from days to even weeks in extreme conditions. Unfortunately, in several instances this inability to address a problem immediately, as can often be with onshore or near-shore systems, has proven to be the greatest challenge in the GoM. Personnel simply cannot safely operate in heavy seas and once a net, stanchion, mooring rope or chain, or any other part of the cage is compromised, waiting for the weather to subside is the only option. Frequently this means that what begins as a minor issue, combined with adverse conditions over several days, eventually causes major damage and there is absolutely nothing on-site personnel can do to prevent it. In some cases main component issues such as mooring failures or broken structural pieces will not result in a permanent setback to a project. Other situations, however, such as gaping holes in netting, cages breaking free and going adrift/sinking, or catastrophic failure of an entire cage system present an entirely different set of circumstances. The offshore environment is extremely challenging and it should be noted that every project in the GoM to date has had one or several of these events occur, often simultaneously.

In addition to the high energy environment of the GoM, another serious issue with netting and other containment materials is biofouling. The wave and current forces exerted on the cage systems stress the components and as barnacles, hydroids, and other organisms accumulate this stress increases. Antifouling paint and other coatings are available and were applied to cage materials however these are meant to reduce biofouling and are not capable of eliminating it altogether. Each year during the spring and early summer the GoM waters begin to warm and a significant amount of fouling occurred very quickly on the cage systems. The only options available are to either clean a cage in place or replace components when the accumulation becomes severe. Needless to say, the challenge of changing a 30–40 m diameter net that weighs several tons in the offshore GoM environment resulted in the cleaning option being employed. Figure 13.4 shows the preventative effect of copper based antifoulant paint on fiberglass panels on the left, with the top row being the treated samples. On the right the drag created by a virtual carpet of hydroids is seen on cage netting in a strong current. In addition to creating additional stress on all the system components, the deformation of much of the netting also effectively reduced the cage volume significantly. Any future offshore projects in the Gulf, however, will have to seriously consider biofouling and how to prevent and adequately deal with the inevitable growth of numerous marine organisms, particularly on the netting or containment materials.

Logistically speaking, operating at exposed locations offshore is significantly more expensive than onshore and near shore sites, largely due to transportation costs. Personnel, cage systems, maintenance equipment, fish, and feed are some of items that have to be transported by either air or sea to the project site whether the platform involved is manned or unmanned. Both platform situations have been tried during the GoM projects and each had its advantages as well as disadvantages. Certainly having a large, stable structure with multiple decks, living quarters, a power supply and crane in an otherwise uninhabitable offshore environment is an asset to an aquaculture venture. In the two projects off the coast of Texas, cages were either attached directly to the legs of a platform or mooring lines from the system were connected to the structure(s) at various points as shown in Fig. 13.5.

Fig. 13.4 *Top* Antifouling effect of copper based paint (*top row* are treated samples). *Bottom* virtual carpet of hydroids on cage netting

13.3 Past Projects

The history of mariculture utilizing offshore platforms in US waters begins in 1990 off the coast of Texas (Chambers 1998; Kaiser 2003). During the next five years MNE, a wholly owned subsidiary of Occidental Petroleum, embarked on a project to assess the feasibility of using oil and gas platforms as a base of operations for fish production. These included both manned and unmanned structures located 11–54 km offshore at depths of 20–80 m in both state and federal waters. Several cage designs were deployed, including both surface and submerged systems all of which were connected at some point to the platform itself. Various types of feed units were designed and placed on the platforms and company biologists would visit the projects sites every 1–2 weeks to inspect the cages and fish, re-supply the feeders, and perform general maintenance wherever required.

Red drum *Sciaenops ocellatus* was the primary species used during the project although on one occasion a smaller prototype cage was stocked with Florida pompano *Trachinotus carolinus*. Red drum from 30–85 g were acquired and transported to the project sites utilizing offshore crew boats in a fiberglass holding tank with supplemental pure oxygen. Stress and subsequent mortality was a

Fig. 13.5 Dunlop Tempest 4™ 18,000 m^3 cage system in 40 m of water at the platform site 54 km offshore on the central coast of Texas

challenge and it was not uncommon to experience losses of 25% or more during the transport depending on a number of factors. Once in the cage and after commencing feeding however, the fish exhibited very good overall health and no incidence of disease or parasitic outbreaks were observed. Grow out of red drum for 6–12 months to a market size of 0.7–1.0 kg at final harvest densities of 7–40 kg/m^3 was successful on three occasions totaling approximately 7300 kg (Chambers 1998). Though not a significant amount of production in terms of commercial volumes, this project stands alone as the only example of fish successfully stocked, fed, and harvested offshore in the Gulf of Mexico to date (Fig. 13.6).

The cages that survived the extreme GoM conditions during the course of the project were smaller, submerged designs whose cost per cubic meter would make them uneconomical for a large scale operation. Results of the MNE project demonstrated that the fish growth and acclimation to the cage system were very good and maintaining them from a biological standpoint was not particularly difficult. The maintenance of cage system components on the other hand, combined with the logistics of supplying feed and the production costs of simply operating offshore resulted in the shutdown of the project in 1995.

The next project along the Texas coast was a joint venture with Shell Oil company called Seafish Mariculture which took place from 1997–1999 (Kaiser 2003). The site chosen for the cages was an active platform complex 54 km offshore of the middle Texas coast in 40 m of water. This project differed from MNE in that it was the first commercial scale cage installation effort with biologists living

Fig. 13.6 A portion of the 1.0 kg red drum harvest during the MNE/Occidental project in 1995

on the platform full time to monitor and maintain the systems. Two person crews alternated during a 7 day on, 7 day off schedule which was coordinated with planned helicopter transport of platform personnel to minimize costs. Cage system supplies, fish food, fuel, water, and anything else needed for the project was delivered by crew boats out of Galveston, Texas and also coordinated with previously scheduled trips to increase efficiency. The platform was outfitted with permanent living quarters, a 7.3 m service vessel that could be craned off the platform, and a pneumatic Akva automated feed system with hoppers that held several tons of fish feed.

The cages that were tried during the project were both systems used in the salmon industry consisting of a circular or hexagonal floating collar portion, stanchions along the circumference, and a 30–40 m diameter cage with a weighted net portion approximately 15 m deep. The first system was similar to many currently used around the world and was constructed entirely of high density polyethylene (HDPE) and featured a double collar ring at the surface. The cage was constructed onshore at a terminal in Galveston and then towed to the site, moored, and had the main net installed along with an interior nursery cage to allow transport of smaller fish to the site (Fig. 13.7).

The system was situated between two platforms with half of the eight mooring lines connected to the legs of the structures and the other half anchored several hundred yards away with concrete blocks and anchors common to the aquaculture industry. Initially, the system performed adequately and was compliant enough to absorb the daily equipment stress as well as the periodic heavy seas that characterize the Gulf (Fig. 13.8).

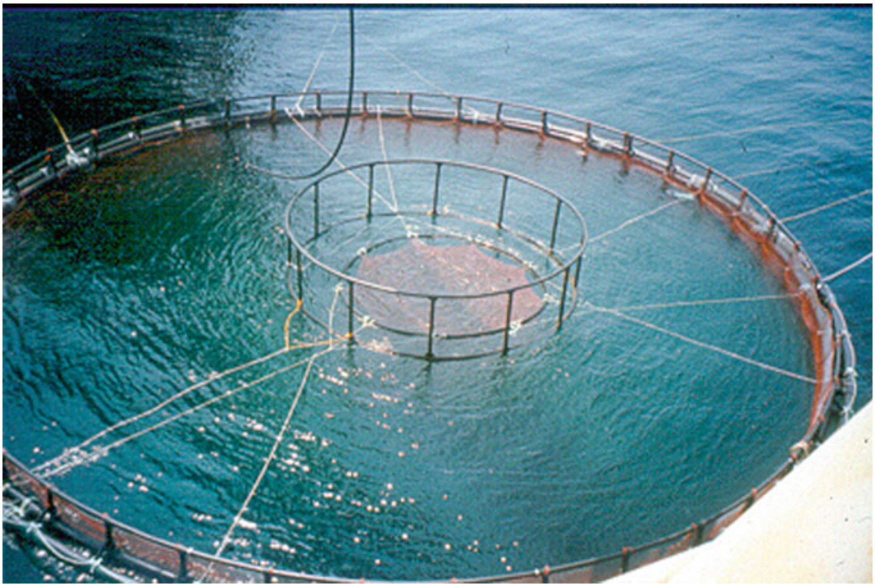

Fig. 13.7 10,000 m^3 double ring HDPE 30 m diameter net pen moored between two platforms off of the central Texas coast

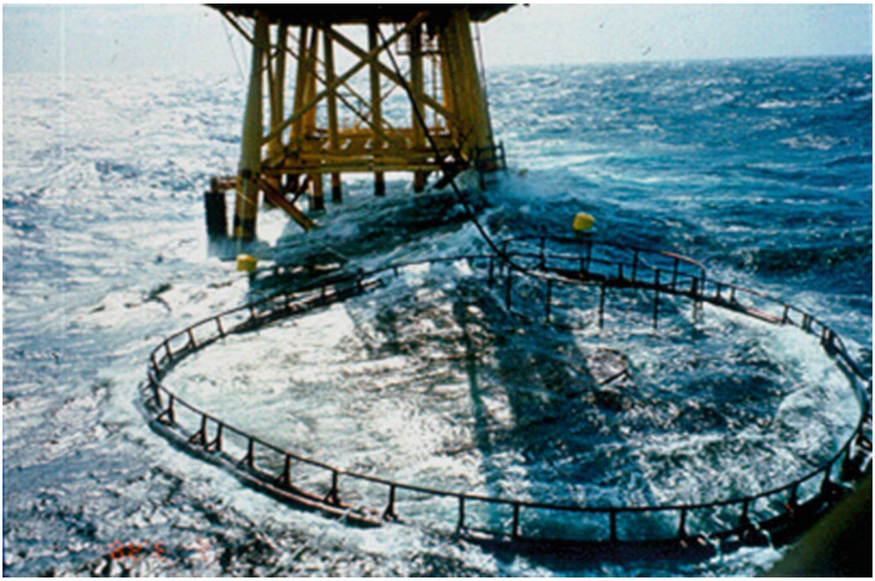

Fig. 13.8 Typical 4–5 m winter seas moving through the cage and platform site

While HDPE is a strong and versatile material used globally in numerous cage culture applications, the high energy surface action in the GoM exerted forces on the cage which eventually began to break various components, especially the stanchions and polysteel rope connections to the top of the net. This damage combined with a particularly active tropical season during 1998 proved to be too much and the system was totally destroyed by a storm and several thousand red drum were lost in the process.

The next system deployed was an 18,000 m^3 Dunlop Tempest™ cage system consisting of 0.4 m diameter 16 m long pressurized rubber hose sections connected by metal flanges at each juncture of the octagonal structure. This cage was located 100 yards from the platforms and attached to the legs of the structures in addition to mooring lines spread in different directions with concrete blocks and anchors (Fig. 13.9). Designed for use at very exposed offshore locations, the cage was extremely strong and the floating collar portion in particular was able to withstand tremendous forces during the project. As is the case in most cage culture operations however, the netting can become easily compromised for a variety of reasons and a significant amount of time was spent in the water patching holes as well as cleaning biofouling on the net. Staying ahead of the maintenance required on a large system proved problematic during the project and it was a constant challenge for personnel

Fig. 13.9 Dunlop cage deployed adjacent to the platform complex during the Seafish Mariculture project in 1998 during typical 1–2 m seas

to maintain the integrity of the cage. Damage would occur during a storm or heavy seas, repairs would be made quickly if time allowed between weather events, and then the next round of damage would occur. There were several thousand red drum stocked into the cage which grew well and the feed unit used on the project performed very well when the feed tube stayed attached as designed.

The project was ended abruptly and unexpectedly in 1999 when it was decided the cage needed to be moved as soon as possible to make room for pipeline construction in the area. Moving a large cage and moorings in the offshore GoM waters is a daunting task in perfect conditions and an impossible one in marginal or bad conditions. During this process the cage ended up entangled in the legs of a platform, the net was compromised, and for all practical purposes that was the end of the Seafish project. Several fish samples were taken along the way, but no significant amounts were ever brought to shore or harvested during the two year venture. A great deal was learned however in terms of what to expect and plan for during installation, feeding, and maintenance of large cage culture systems in the open GoM.

Though not directly utilizing a platform, there has also been one federally funded effort to conduct offshore aquaculture research in the GoM. This research took place from 2000–2003 and was initiated with the formation of the Offshore Aquaculture Consortium (OAC) which was a collaborative, Gulf-wide research and development program tasked with gathering primary scientific data regarding offshore aquaculture. The project site was in federal waters 40 km off the Mississippi coast at a depth of 26 m and within a few hundred meters of an active platform whose only involvement was for observation of the cage. The position of the OAC investigators was one of specifically not using a platform in an effort to have an autonomous cage system in the offshore Gulf waters. A commercially available Sea Station™ 600 m^3 system was installed with a single point mooring whose efficacy, ironically, was questioned at a workshop organized by the OAC in 2000. After being deployed for 50 days a component of the mooring failed and the cage was adrift for 40 days before being located and towed back to shore for repairs. The cage was subsequently redeployed with a three point mooring system and although fish were stocked into the system no significant amounts were harvested during course of the research. Funding was discontinued and unfortunately what began as an excellent opportunity for an offshore aquaculture demonstration project in the GoM ended abruptly in 2003. A detailed description of the entire OAC project can be found in the final report to NOAA (Bridger 2004).

13.4 The Future

Despite the challenging conditions, interest in offshore aquaculture production in the Gulf of Mexico still exists. From a technology standpoint, new and improved aquaculture systems are available that can survive and produce fish but the primary question is can this be done profitably offshore? Thus far, in the GoM the answer to that question has been no based on the experiences of the projects to date. A comprehensive economic feasibility study on using oil and gas structures in the GoM for mariculture concluded that at the present time it not likely to be a profitable venture (Kaiser et al. 2011a). Liability and decommissioning issues for the structure itself have long been identified as the major impediments to mariculture using platforms in the GoM and this situation remains true to the present (Dougall 1999; Kaiser et al. 2011a). The regulatory environment and permitting issues in offshore waters of the US have hindered development for two decades and investors have simply moved their offshore cage culture projects to other countries in many cases (Upton and Buck 2010). Internationally, there are only a couple of locations using dedicated platforms for mariculture production, one in the Mediterranean and the other in Japan. The platform in each case has multiple cages attached to it and acts as the operational center from which the growout systems are fed and maintained (Kaiser et al. 2011b). Considering the high energy environment, possibility for hurricanes, platform cost and liability issues, logistical challenges, and economic reality of offshore mariculture, it is not surprising there are no cage systems currently in the Gulf of Mexico.

That being said, it is the authors assertion that in the future a project with the right location, substantial capital investment, experienced personnel, and a good cage system will profitably grow fish in the Gulf of Mexico. The scenario will likely involve multiple submersible cages near a platform with a crane that houses a feeding unit capable of holding 200+ tons of feed which can be operated remotely if required. The structure may or may not be associated with an energy company and it may turn out that a platform put into place and designed specifically for a mariculture project, while certainly expensive, might be a better long-term option. The potential of refurbishing and reusing a decommissioned platform has also been suggested (Kaiser et al. 2011b) and may offer some advantages with regards to the liability issues that are associated with ownership.

An alternative to a platform proposed in the OAC final report is an aquaculture support vessel (ASV) which could be a large catamaran style vessel or more likely a lift boat type commonly used for nearshore maintenance on platforms (Bridger 2004). Several issues come to mind that make that option less attractive considering the high energy real world conditions in the GoM. Lift boats are very slow vessels (5–7 knots) that can only travel in decent seas—this complicates the logistics of anything in the 30+ km range. Because of depth requirements, these are the most likely areas for a cage project requiring tons of feed every day so faster crew boats would be required weekly to transfer the feed to a lift boat on a continual basis. In addition, once an operation is established with multiple cages and a substantial investment in fish stock, there can be no interruptions due to lift boat vessel maintenance, annual US Coast Guard inspections, and other mechanical issues. Because of this need for continual operation a second, backup ASV would be required for any large scale project that is conducted in GoM offshore waters. Assuming the cage site is in the preferred 30–50 m water depth, the cost of lift boats that can operate at these locations would be in the $5–20 + million dollars per boat range and would require the expense of two rotating teams of crew members as well. Lift boats cannot stay on site in all types of weather meaning that by pre-emptively heading in before severe conditions, not only are no personnel at the project site, but the feeders will not be getting filled on schedule, and fish will not be growing. Taken together, the cost of at least two ASV vessels, crews to man them, weekly supply boat runs, and the need for multiple feed buoys that must work flawlessly, the platform option starts to look better in comparison. Except for one hurricane evacuation during the Seafish project, the platform as a base of operations allowed personnel to remain on site continuously for two years regardless of the sea state and weather. This ability, combined with having a topside automated feed system instead of feed buoy(s) and virtually limitless feed storage capacity on multilevel decks begins to present a scenario where millions of kilograms of product could be cultured in the open ocean environment.

With regards to feeding, while a large buoy seems like an obvious alternative to using a platform there are several issues that warrant consideration for the GoM application of such a system. First, survivability of such a buoy is paramount since having several hundred thousand kilos of fish in culture is irrelevant if there is no way to reliably feed them. Designing a buoy that is able to maintain a specific position relative to the cages during normal choppy Gulf conditions, frequent 3–4 m seas, occasional 7+ m wave heights, and hurricanes is an engineering challenge at the very least. This technology is very expensive, but it has been demonstrated at an offshore site in New Hampshire (Fig. 13.10) and some of this research could be applied to future Gulf projects (Atlantic Marine Aquaculture Center 2007, http://ooa.unh.edu/). Feed barges up to 450 ton are used in protected waters (1–2 m) in Norway, Canada and Chile. Unfortunately, these pneumatic feeders would not survive in the GoM environment. Other possibilities for feeding a large scale farm include retrofitting a 40 m fishing vessel that can plug into a mooring and feed distribution system to each cage. If a severe storm is approaching, the vessel could detach and head back to port. Having a portable feeder would allow you to conduct maintenance, refueling, personnel exchange and fill the feed silos at a safe harbor instead of offshore. Offshore mariculture on a commercial scale involving millions of dollars of equipment and fish will likely need to be manned operations as well, a role that a platform and appropriate tender vessel could accomplish. Without thinking along this economy of scale involving systems that provide tens of thousands of cubic meters of water volume in which to grow marine fish offshore, the benefits of operating in the open GoM will not be realized.

Experiences gained after many years working on offshore aquaculture systems using platforms in the GoM can be distilled down into a partial list of some important points.

1. Eliminate modes of failure in all parts of the production system. Keep it strong and simple wherever possible as the offshore environment will reveal any component weaknesses, usually very quickly and often catastrophically.
2. Ocean conditions and weather determine everything offshore so plans must be made and adjusted accordingly. Nothing can be forced if conditions don't allow it as the ocean will always win in that situation.

Fig. 13.10 Aquamana 20 ton feed buoy deployed at the University of New Hampshire Open Ocean Aquaculture site located 13 km offshore. The hydraulic feeder fed four submerged cages in sea conditions seas up to 10 m

3. Redundancy and backup systems where applicable, especially with regards to moorings, which are arguably the most critical components of the cage system.
4. Prepare as much equipment while the system is onshore as possible. It becomes exponentially more difficult to work on nets, stanchions, cage ties, shackles, and anchor lines the moment it enters the water.

The future of mariculture worldwide is a bright one. Demand for marine plants and animals is increasing and, while wild caught fisheries are essentially flat or in decline, the culture of these products is attempting to meet that demand with increased supply each year. Where the US fits into this future is unclear given our past record of low marine aquaculture production, onerous permitting requirements, and vague regulatory picture, especially in offshore waters. In the US, the Gulf of Mexico is an area that may play a role in domestic offshore mariculture production, should it ever develop on a commercial scale. This “audacious hope” for the GoM, as described in Sims (2015), will hopefully become a reality in the near future when the right concept is put into action with adequate investment. This will not happen, however, until the liability and regulatory issues in US federal waters and economic challenges of production are resolved in order make it a more attractive venture to investors.

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