Open Ocean Aquaculture

Authors: Ben Belton, Jeremy Brown, Lynn Hunter, Tracie Letterman, Anne Mosness, Mike Skladany

February 10, 2004

Table of Contents

Introduction	**3**
1 What is Open Ocean Aquaculture?	**3**
2 The Current Status of Open Ocean Aquaculture	**4**
3 Environmental Considerations	**4**
4 Social and Economic Factors	**7**
5 Policy	**8**
6 Conclusion and Recommendations	**10**
Footnotes	**12**
Appendix (Figure 1, List of Acronyms, Scientific Names, Acknowledgements)	**14**

Introduction

Open Ocean Aquaculture (OOA) is emerging as highly significant redesignation of the U.S. Exclusive Economic Zone (EEZ) that will allow industrial usage of our commonly owned waters by private corporations. The aggressive promotion and funding of open ocean aquaculture by several federal agencies is taking place despite a number of problematic legal, political, social and environmental issues. Our objectives in this paper are to: 1) outline the context and current status of open ocean aquaculture 2) draw conclusions regarding a range of its potential impacts, 3) make policy recommendations.

1. What is Open Ocean Aquaculture?

Open Ocean Aquaculture Defined

Open ocean aquaculture is defined as the 'rearing of marine organisms under controlled conditions in the EEZ—from the three mile territorial limit of the coast to two hundred miles offshore. Facilities may be floating (for example, net pens for rearing of finfish and rafts from which strings of mollusks are suspended), submerged (fully enclosed net pens or cages moored beneath the water surface), or attached to fixed structures' (1). (See Appendix, Fig.1). The terms 'open ocean aquaculture' and 'offshore aquaculture' are interchangeable.

Background

The National Aquaculture Act (NAA) of 1980 states that, 'it is the national policy, to encourage the development of aquaculture in the United States' (2). The NAA is the driving force behind subsequent aquacultural development. Offshore aquaculture was recognized in 1995 by the federal Office for Technology Assessment as a potentially viable way of raising fish. At this time, Sea Grant Programs, funded by the National Oceanic and Atmospheric Administration (NOAA), began undertaking preliminary research exploring the technical and economic feasibility of the concept. The Department of Commerce (DOC) Aquaculture Policy drafted in 1999 pushed the process further, demanding an increase in 'the value of domestic aquaculture production from the present $900million annually to $5 billion' by 2025 (3). Federally funded R&D has continued apace in conjunction with private business and several universities. NOAA has been instrumental in drafting an offshore aquaculture bill, for presentation to congress in 2004.

The offshore process is founded on two rationales. The first; a need to redress the US seafood trade deficit, surpassed only by importation of oil and automobiles and currently running at just over $7 billion (4). The second; avoiding user conflicts over coastal aquaculture in locations that, 'are being increasingly contested by competing interests such as the fishing industries, recreational boaters, adjacent landowners and environmentalists' (5). More recently, self-sufficiency in food production has been offered as a solution to homeland security concerns.

2. The Current Status of Open Ocean Aquaculture

Table one below summarizes the current status of OOA in the EEZ of the United States. We give location, identify the lead institution and provide status of each species as: **E**—experimental, **R**—preliminary research, **D**—Demonstration, operating on pilot scale, **C**—Commercial operating as an aquabusiness. (This is a partial listing)

Table 1: U.S. Open Ocean Aquaculture Sites

Location	Species-status	Lead Institution
Alabama-Mississippi	Red Drum—D	Mississippi-Alabama Sea Grant
Florida	Amberjack—R Red Snapper—C * Cobia—C * Florida Pompano—C* Red Drum—C *	University of Miami Florida Offshore Aquaculture, Inc.
Hawaii	Pacific Threadfin - C Amberjack—E/D	Hawaii Sea Grant, Oceanic Institute, Cates International Inc
Massachusetts	Engineering: Robofeeder/cages	Massachusetts Sea Grant/MIT
New Hampshire	Blue Mussel—D, Sea Scallops—E Summer Flounder—D, Halibut—E Cod—E, Haddock - E	University of New Hampshire, New Hampshire Sea Grant
Puerto Rico	Cobia—C, Mutton Snapper - C	Snapperfarm Inc
Texas	Red Drum—E/D	Texas Sea Grant/Texas A&M

*permit pending (See Appendix, Table 3 for Scientific names)

3. Environmental Considerations

Fish Meal Consumption and Trophic Levels of Potential Species

Most industrially cultured marine finfish species are carnivorous and consume large amounts of fish meal and fish oil, making them net consumers of fish (6). This feed, is derived largely from intensive extractive fisheries conducted off the coasts of developing nations in the Southern Hemisphere. 'Even with improvements in feed and breeding, three pounds or more of wild fish are still required to produce one pound of farmed salmon or other carnivorous fish' *ibid*. An ecological footprint analysis can also be utilized to understand the impacts of fish farms. This measures the sum of biological material and energy inputs into a system. For example, one ton of industrial farmed Atlantic salmon has an ecological footprint approximately twice that of commercially captured sockeye, chum or pink salmon (7). The marine area needed to produce the feed consumed in a salmon farm is 40,000—50,000 times greater than the area of the farm itself (8).

It is likely that 'OOA will begin with growing and processing high value fish and seafood' species (9) in order to offset large investment costs. All of these fish will be carnivorous and have a trophic level—'position in the food chain, determined by the number of energy-transfer steps to that level' (10)—similar to or higher than that of the Atlantic salmon (Table 2). This is crucial in light of the above discussion of fish meal consumption as the higher a species' trophic level, the less efficient its conversion of feed to body mass will be. i.e. the ecological impact of raising these species will be at least as large as it is for salmon, causing an even greater global net loss of edible fish protein.

Table 2. Trophic Level And Location of 6 OOA Species (11)

Species	Trophic Level	Location
Summer Founder	4.5	NH
Cobia	4.5	FL, PR
Amberjack	4.5	FL, HI
Atlantic Cod	4.3	NH
Red Drum	4.3	AL, FL, TX
Atlantic Halibut	4.2	NH
Atlantic Salmon	**4.2**	**Worldwide**

Fish Diseases

Transmission of almost all fish diseases takes place through water. Offshore net-pen design allows for the captive fish to share water with wild fish, leading to inevitable biomagnification and transfer of disease vectors and parasites. Caged fish may contract disease from wild populations, but the lack of predation and extraordinary host density inside net-pens can result in undetected or untreatable illnesses becoming inadvertently cultured alongside the fish. 'In a sea-cage, low juvenile mortality [for parasites such as sea lice] greatly shortens parasite generation time,' promoting faster evolution towards increasingly virulent strains. Parasites and disease are then transmitted back to the wild populations from whence they came, possibly at a higher level of pathogenicity (12). There is strong evidence documenting the lethal sea lice infestation of smolts close to fish farms in estuaries on the routes of migratory salmonids (13).

NOAA's 5 year fisheries strategic plan for sustainable fisheries promotes, 'the commercial rearing of at least 7 new species' (14). Many more are at the experimental and developmental stage. They are likely to bring with them a host of unforeseen environmental problems, including disease, if cultured at commercially viable densities since we have minimal knowledge of their ecology and epidemiology. (There are now over 255 described diseases of salmon, most of which were unknown before Atlantic salmon were cultured) (15). Strong ocean currents found offshore will simply distribute these pathogens over larger ranges with unknown consequences.

Water Quality

The literature of OOA generally assumes that pollution caused by aquaculture will pose less of a problem offshore because of the greater volumes of water available for its dispersal. Research carried out by the University of New Hampshire (UNH) and others, indicate minimal impacts on water quality and bacterial communities in the vicinity of experimental OOA sites. Extrapolating from these findings, however, is problematic as experimental facilities are designed simply to test the feasibility of rearing organisms offshore, but are not anywhere near the capacity required for an economically viable farm. This seeming reluctance to vigorously test industry related impacts at appropriate production densities can be seen in past NOAA studies (16), calling into question the agency's benign opinion of effects.

Escapes

The aquaculture industry, using the same strategies that have proven inadequate in preventing fish escapes from coastal facilities, offers only new net-pen designs and management plans for OAA. The industry's dismal record is well documented. For example, 'Up to two million salmon are thought to escape from farms around the North Atlantic each year' (17). Once free, these fish may quickly assimilate into the wild, and can compete with wild stocks for food, habitat, and mates. Interbreeding with native fish results in genetic modification and degradation, and increased potential for disease and parasite transfer to wild stocks (18). In many regions, such as off the coast of Maine, 'farmed escapees vastly outnumber wild salmon in some spawning rivers' (19).

Although most species slated for OOA development are not andronomous, as is the case for salmonids, inherent dangers remain, particularly with the introduction of exotics. Initial halibut and cod culture has focused on the Atlantic species, yet there is no reason to believe that their introduction into the Pacific would yield any lesser degree of competition, interbreeding and genetic degradation. The likelihood of GE fish escaping from ocean pens raises even more serious ethical and biological issues.

Genetically Engineered Fish

Current aquacultural trends strongly indicate a push toward the eventual use of genetically engineered (GE) fish. Genetic engineering is defined as 'a set of techniques from molecular biology (such as recombinant DNA) by which the genetic material of plants, animals, micro-organisms, cells and other biological units are altered in ways or with results that could not be obtained by methods of natural mating and reproduction or natural recombination'(20).

Aqua Bounty, a private aquaculture company is currently seeking Food and Drug Administration (FDA) approval to market its transgenic salmon for human consumption. In addition to transgenic salmon there are at least 35 other genetically engineered fish species that could be on the market shortly if GE salmon gains approval from the FDA (21). The recent commercial sale of 'Glofish' (a zebra fish for use in home aquaria, altered to express a fluorescence gene derived from sea coral) demonstrates that GE fish can enter the market place without any rigorous environmental assessment or public debate.

There is little information that relates specifically to the place of GE fish in OOA. However, the NOAA Code of Conduct implies that these organisms are acceptable, in stating that; 'priorities to conserve genetic biodiversity should not deter research to improve breeds in ways which will avoid any future threats to the environment' (22). If this technology does yield faster growing fish species, as promised, it will be imperative that the aquaculture industry deploy them because of the competitive advantages that they appear to offer.

4. Social and Economic Factors

Open Access, Private, Public and Common Property

Marine property and associated property rights over the water column and bottom lands falls under states' jurisdiction as articulated in the public trust doctrine. The doctrine states that, 'the public has the right to use and enjoy trust lands, water, and resources for a variety of uses'(23). Individual states own the lands and water in the public interest. States have an obligation to, 'protect the public interest from any use that would substantially impair the trust'(24). There is currently no statutory authority to lease private aquaculture in federal waters. At stake is the leasing of offshore sites for aquaculture where there is no clearly defined sense of private property. 'Public property rights ... prevent the conveyance of exclusive private use rights to submerged lands or water in perpetuity,' subjecting the aquaculturist to, 'public and private riparian rights and to government oversight'(25). Complicating this matter further is the direct and indirect involvement of well over twenty federal agencies, indigenous treaty rights and over one hundred statutes, the majority involving direct compliance.

Increasing opposition to coastal aquaculture has heightened interest in developing the EEZ. Overlapping uses and conflicts must still be resolved with fisheries management councils, subsistence, recreational and commercial fishers, the Army Corps of Engineers, and the Navy. To defend itself from competing marine activities, the industry is seeking, 'mechanisms for granting a range of rights to allow private aquaculture in public waters.' These perceived property 'rights' would include; 'the right to use a particular location for aquaculture,' 'the right to exclude others from the site,' 'the right to discharge wastes into public waters,' the right to introduce chemicals into public waters,' and 'the right to protect private property placed at the site'(26).

Interest is growing for other uses that would seek to obtain similar rights to the EEZ. These include oil and gas drilling, the abandonment of superannuated rigs, alternative electricity generation, sub sea mining, waste disposal, commercial rocket launching, and marine reserves. With pressure mounting for secure private control of large portions of the 4.3 million square miles in the US EEZ, the sale of rights is a logical avenue for a government with mounting deficits. Given the billions of dollars raised by the US government in the 1990's by the sale of radio frequency rights, this is indeed likely to be considered.

Economic Viability, Employment and Their Social Consequences

Investment in this new industry will be capital intensive, hinging largely on research and development of new technologies needed to achieve economies of size and scale. NOAA and Sea Grant are subsidizing this applied research to minimize risk and attract investors. In addition to capital costs, the physical location away from shore will carry high variable costs such as fuel, transport, and equipment. Time and expense incurred traveling to the sites will require minimization of labor costs, with automation instead of human workers performing many tasks. Ocean Spar Technologies, for example, has designed the 'Robofeeder' to 'perform [fish feeding] functions normally carried out manually' (27). To maximize profit, OOA operations will depend on heavy long-term financing necessitating corporate ownership and integration of production and post-harvest processing. To reduce their economic risk, the aquaculture industry has been campaigning for guaranteed investment security by federal and state agencies during the establishment of OOA.

Because of innate similarities, the salmon aquaculture industry provides a strong model on which to base predictions about employment, ownership patterns and social impacts of OOA. Salmon farming in British Columbia, Canada, grew largely out of individually owned 'mom & pop' operations which spread wealth horizontally to local communities. In 1989 there were 75 companies in operation. Pressure to rationalize, arising from increased efficiencies in the Norwegian industry and lower unit costs generated by rapid Chilean expansion, has resulted in 5 multinationals, now controlling 109 of the 131 B.C. licenses and 82% of production. Only 9 tenures, '(7% of the total) are controlled by companies majority owned by British Columbians,' leaving little revenue in local economies (28). Despite a five year moratorium on salmon farming in B.C, production rose 94% over the period due to improved efficiencies. During this time however, employment within the industry only grew by 5.6%. The 'Norwegian, and Scottish experiences show that zero job growth across the industry is even more likely' *ibid.*

Crashing salmon prices fuelled by overproduction and Chile's growing market share; up from zero in 1984 to 454,400 MT in 2002 (29), have led to a dramatic decline in the value of the North American Pacific salmon fishery with devastating repercussions for those dependant upon it. Prices for Pacific wild-caught salmon in 2002 'were 63-82% lower than average prices for the period from 1988—1992,' meaning that 'many salmon fishers in the region…. can no longer afford to stay in operation and pay off their debts' (30). Many fishing vessels and ancillary businesses are family owned, providing an economic multiplier that presently generates substantial revenue in coastal communities. Still thriving capture fisheries such as halibut, which maintain these businesses, would also likely be devastated by downward pressure exerted on fish prices by large-scale OOA. Given the adaptability of globalized production, OOA operations will rapidly relocate to any area providing lower production costs and laxer regulations, resulting in little discernable benefit and serious challenges for coastal inhabitants of the United States.

5. Policy

Funding

For a number of years, NOAA and other federal agencies have channeled millions of dollars into open ocean aquaculture R&D through initiatives such as the Advanced Technology Program (ATP), (set up to facilitate bridging 'the gap between the research lab and the market place,' by sharing with industry, 'the relatively high development risks of technologies that potentially make feasible a broad range of commercial opportunities') (31). The Saltonstall/Kennedy Program, the Fisheries Finance Program and the National Sea Grant College Program, in addition to NOAA's in-house research programs have also been used to fund marine aquaculture development (32). Private business is being aided through research and development largely carried out at universities. The University of New Hampshire, Texas A&M, Auburn, the University of Hawaii and University of Puerto Rico are all key Sea Grant funded aquaculture research facilities. The Tropical, Sub-tropical, North Eastern and Southern Regional Aquaculture Centers, Northwest and Alaska Fisheries Science Center are bodies also engaged in similar research. NOAA spends an estimated $8 million on aquaculture annually and will receive an additional $30 million sum if the 2004 offshore bill is successful (33).

Based on the British Columbian salmon farming model, it is questionable, 'whether the aquaculture industry is contributing positively to government revenue, since subsidies, tax credits and indirect government expenditures related to industry are substantial.' As funding for R&D is governmental, 'net government revenue generated by the industry is…potentially non-existent' (34). There is little reason to believe that this will be any different as OOA develops in U.S. waters.

The close bond that exists between private aquaculture ventures and state and federal regulatory agencies has led to inadequate oversight and peer review. This "revolving door" between the public and private sectors has made the objectivity of scientific recommendations emanating form these sources highly questionable. A directly comparable situation exists in the UK where, in the case of GE crops, 'instead of objective, rigorous testing, we are presented with assumptions, projections and mathematical models, many of which have been produced directly or indirectly by the very companies seeking to introduce these crops' (35).

The Context of Decision Making

The development of offshore aquaculture has been cloaked in secrecy and characterized by an extreme disinclination to garner meaningful public and stakeholder input. Promotion of OOA by NOAA, Sea Grant funded universities and a handful of companies continues to forge ahead despite a lack of evidence that there will be any benefits except to career academics, bureaucrats and entrepreneurs. The implications of the broadly distributed costs have not been addressed at all. Federal agencies are currently facing the impacts of a spiraling budget deficit and NOAA has recently undergone major restructuring. Promoting OOA as a means to ensure homeland food security could be an appealing way to ensure future funding.

Content of the 2004 Offshore Aquaculture Bill

NOAA's draft Code of Conduct has been the most significant OOA policy document to date. It will be published in 2004, and much of its content will be replicated in the findings of forthcoming offshore aquaculture bill, which will be presented to the U.S. Congress in 2004. The Code of Conduct suggests that it is necessary to:

1) demonstrate that OOA is technologically possible
2) streamline the permitting process and facilitate private control of waters in the EEZ
3) foster joint public/private sector investment in order to reduce initial risks for business
4) consolidate all bureaucracy under a single regulatory body.

More specifically, the bill delineates two types of permit for offshore sites. 1) A site permit for a minimum of 10 years, 2) an operating permit dependent on species, seabed, anchoring, consistency with the Coastal Zone Management Act, and compatibility with other users. There will be a 'one stop permitting process,' and operators will have to meet standards consistent with the species being raised (these have yet to be defined as many species are experimental). Permits would have annual fees, which will go into an aquaculture fund. They will be transferable and available to any citizen. Permits could be revoked, and there are guidelines for environmental monitoring which would be reduced if farms comply with standards. These standards will be set through partnership with industry in association with scientific studies. There will be Department of Commerce financial assistance, R&D partnerships with industry for feasibility studies, and financial assistance for farms that are not economically viable (36).

The bill's most controversial aspect is that it would exempt offshore aquaculture facilities from the Magnuson-Stevens Fishery Conservation and Management Act (1996), allowing foreign companies and individuals to own offshore sites. This is significant because the purpose of the act is to conserve and manage the marine and Continental Shelf fishery resources of the United States, by exercising '*sovereign* rights for the purposes of exploring, exploiting, conserving, and managing all fish within the Exclusive Economic Zone' (37).

The Role of NEPA

The National Environmental Policy Act (NEPA) is the 'basic national charter for protection for the environment.' 40 C.F.R. 1500.1. Its purposes are to, 'help public officials make decisions that are based on understanding of environmental consequences, and to take actions that protect, restore and enhance the environment,' and to, 'insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken.' *ibid* § 1500.1(b),(c). To accomplish these purposes, NEPA requires all federal agencies to prepare a 'detailed statement' regarding all, 'major federal actions significantly affecting the quality of the human environment ' 42 U.S.C. 4332 (C). This statement is known as an Environmental Impact Statement (EIS). To determine whether an EIS is required, federal agencies must prepare an Environmental Assessment (EA), that provides sufficient evidence and analysis to support the agency's determination on whether a proposed action will significantly affect the environment. 40 C.F.R. § 1508.9.

In a report prepared for NOAA entitled 'Development Of A Policy Framework For Offshore Marine Aquaculture In The 3-200 Mile U.S. Ocean Zone,' the use of NEPA and a precautionary approach to the review of marine aquaculture projects in the EEZ is strongly advocated (38). Recognizing that there is insufficient environmental data available to support the siting of proposed aquaculture projects in the EEZ, the authors point out that, 'in practice, little has been done to determine which areas offshore are best suited for marine aquaculture development, are environmentally appropriate and are least likely to interfere with endangered species and marine mammals, and with other uses of offshore waters' *ibid*.141. The report recommends that an EIS should be prepared for each individual aquaculture project through an open and transparent public review process *ibid*.146.

6. Conclusion

Open ocean aquaculture requires a substantial policy change that facilitates the de facto privatization of the ocean. This process has been characterized by a willful failure to address critical issues. At every stage there has been a flagrant disregard for the Precautionary Principle, the Public Trust Doctrine, the application of NEPA, legally binding statues and jurisdictions, traditional uses of the EEZ and the long-term environmental consequences of increased bio-industrialization of the Continental Shelf. There has been an almost complete lack of civil societal input into this secretive process, accounted for by the activity's creation for the benefit of the consortium of special interests that conceived it. Following are recommendations and conditions that will institute a greater degree of trust in federal agencies as they oversee the public domain for the benefit of all citizens.

Congress, NOAA, and the Corps of Engineers should immediately impose a moratorium on commercial open ocean aquaculture development until national aquaculture legislation is adopted and comprehensive, open, and transparent regulations are finalized. The following recommendations should be included within this legislation:

1. National standards for OOA must be mandatory. Self-regulatory or voluntary codes of conduct are not acceptable;

2. There must be sufficient notice and at least a 60 day public comment period before deciding whether to issue any OOA permit.

3. No OOA permit will be issued without conducting a rigorous environmental impact statement (EIS) that is consistent with the requirements of NEPA. This includes full consideration of the socio-economic impacts to commercial and recreational fishermen and the impacts to other water uses such as swimmers, divers, and nature enthusiasts. In addition, impacts to endangered species, essential fish habitat, and marine mammals must be fully considered as required by law.

4. No part of the water column or bottom-lands anywhere in the EEZ may be de facto privatized. The cost of leasing OOA must reflect a fair market value. Leases/permits will be temporary and renewable only if compliance with strict environmental regulations is met. Compliance with these regulations are to be ensured by regular monitoring by NOAA, the results of which are to be verified by independent experts.

5. Environmental impacts from net-pen culture must be strongly regulated. This includes adopting regulations and developing technologies that eliminate as fully as possible; fish escapees, disease transfer to wild fish, depletion of global fish stocks for farm raised fish feed, discharges of waste, harm to marine mammals, and antibiotic use.

6. Raising genetically engineered or non-native marine aquatic species is prohibited at any OOA facility.

7. Indigenous peoples' free access to their lands and territories must be fully ensured. Additionally, biological regions and habitats in which their traditional knowledge and foods are based should be fully protected from the development of OOA. Full consultation with Indigenous peoples about OOA in all matters where it may affect their subsistence, right to food, and food security must be legally required.

Finally, we recommend that future aquaculture legislation encourage the development small-scale production of herbivorous finfish species that complement local landscapes and food systems. Aquaculture development needs to be refocused on enclosed, land-based systems rather than encouraging development and pollution within our already fragile marine ecosystem.

Footnotes

1. Stickney, R, "Offshore Aquaculture: technology and policy issues" unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington D.C. (April 1994)

2. National Aquaculture Act, Public Law 96-362, (September 26, 1980)

3. U.S. Department of Commerce Aquaculture Policy, 1999. http://www.nmfs.noaa.gov/trade/DOCAQpolicy.htm

4. Calculated from figures available on the NMFS web-site, (September 2003), www.st.nmfs.gov

5. Chang, B, D. "The salmon aquaculture industry in New Brunswick: why go offshore?" Open Ocean Aquaculture IV, From research to commercial reality. p23 St Andrews New Brunswick, (2001), http://nsgl.gso.uri.edu/masgc/masgcw01001.pdf

6. Weber, M, L. "What price farmed fish? A review of the environmental and social costs of farming carnivorous fish" p24. Seaweb Aquaculture Clearing House, (2003)

7. Tyedmers, P, H. 'Salmon and sustainability: the biophysical cost of producing salmon through the commercial salmon industry and the intensive salmon culture industry," PHD Thesis, The University of British Columbia, (2000)

8. Folke, C, Kautsky, N, Berg, N, Jansson, A & Troell, M. 'The ecological footprint concept for sustainable seafood production: A review" Ecological applications, Vol. 8 (Suppl.1): p.S63-S71. (1998)

9. Benemann, J and Herman, D "An ecological engineering approach to open ocean aquaculture" Open Ocean Aquaculture IV, From research to commercial reality. p23, St Andrews New Brunswick, (2001) http://nsgl.gso.uri.edu/masgc/masgcw01001.pdf

10. "Glossary of bio-diversity terms" European Environment Agency, (2003) http://glossary.eea.eu.int/EEAGlossary/T/trophic_level

11. Calculated using the FAO "Fishbase" website: http://www.fishbase.org/search.cfm

12. Bakke, T.A. and Harris, P.D. "Diseases and parasites in wild Atlantic salmon (Salmo salar) populations." Canadian Journal of Fisheries and Aquatic Sciences, 55 (Suppl.1), 247-266. (1998)

13. Tully, O., Gargan, P., Poole, W.R., and Whelan, K.F. "Spatial and temporal variation in the infestation of sea trout (Salmo trutta L.) by the caligid copepod Lepeophtheirus salmonis (Kroyer) in relation to sources of infection in Ireland." Parasitology 119: 41–51, (1999)

14. NOAA "A code of conduct for responsible aquaculture development in the US Exclusive Economic Zone" p21. (first draft, 2000)

15. Grizzle, R, Ward, L, Langan, R, Schnaittacher, G and Dijkstra, J "Environmental monitoring in the vicinity of an open ocean aquaculture site in the Southwestern Gulf of Maine: some preliminary results" Open Ocean Aquaculture IV, From research to commercial reality. P58, St Andrews New Brunswick, (2001) http://nsgl.gso.uri.edu/masgc/masgcw01001.pdf

16. Bakke, T, Harris, P. 247-266. (1998)

17. Schiermeier, Q. "Fish farms threat to salmon stocks exposed" Nature 425, 571, (2003)

18. Letterman, T. "Letter RE: the center for food safety's comments dissenting from the aquaculture effluent task force subgroup on non-native species" The Center For Food Safety, (January 8 2003)

19. Naylor, R, L, Williams, S, L, & Strong, D, R. "Aquaculture--A Gateway for Exotic Species," 294 Science 1655, 1656 (Nov. 2001)

20. International Federation of Organic Agriculture Movements, "Position on Genetic Engineering and Genetically Modified Organisms," (2003) http://www.ifoam.org/pospap/ge_position_0205.html

21. Reichhardt, T "Will souped up salmon sink or swim?" Nature 406:10-12, (2000)

22. NOAA "A code of conduct for responsible aquaculture development in the US Exclusive Economic Zone" p21. (first draft, 2000)

23. Marine Law Institute. "Improving the legal framework for marine aquaculture: the role of water quality laws and the public trust doctrine," Technical Report for the Northeastern Regional Aquaculture Center, (July 31, 1992)

24. Archer, J, H. “The public trust doctrine and the management of America’s coasts” Amerhurst: University of Massachusetts, (1994)

25. Rieser, A. “Defining the federal role in offshore aquaculture: should it feature delegation to the states?” Ocean and Coastal Law Journal 2: 209-234, (1997)

26. Bunsick, S. “Governing offshore aquaculture: a conceptual framework”Open Ocean Aquaculture IV, from research to commercial reality. p31, St Andrews New Brunswick, (2001), http://nsgl.gso.uri.edu/masgc/masgcw01001.pdf

27. “Unmanned ‘Robofeeder’” Fish Farming International, (April 2002)

28. Marshall, D. “Fishy Business: the economics of salmon farming in BC” Canadian Center for Policy Alternatives, p 9, (July 2003)

29. Gillard, M. ”Aquaculture workshop: salmon” SeaFIC Conference 2003, http://www.seafood.co.nz/doclibrary/conference2003/30may03/aquacultureworkshop_markgillard.pdf

30. Naylor, R, Eagle, J, Smith, W. “Farms or fisheries? Salmon in the Balance” Environment, Vol. 45, number 8, p25 (October 2003)

31. “The advanced technology program,” NMFS/NOAA web-site, (2003), http://www.nmfs.nooa.gov/trade/newgrant.htm

32. “NOAA’s national marine aquaculture initiative: seafood and technology for the future” NOAA Magazine Online story 25, (March 6 2002), http://www.noaanews.noaa.gov/magazine/stories/mag25.htm

33. Marshall, D. “Fishy Business: the economics of salmon farming in BC” Canadian Center for Policy Alternatives, p17, (July 2003)

34. Ching, LL. “Farmers want review of publicly-funded science,” (2003), http://www.i-sis.org.co.uk/FARM.php

35. Keeney, T. (Deputy assistant secretary, US dept. of Commerce—NOAA) comments following speech: “US policy, perspective and direction” at the Conference on Marine Aquaculture: Effects on the Alaska Fishing Industry, (November 18 2003)

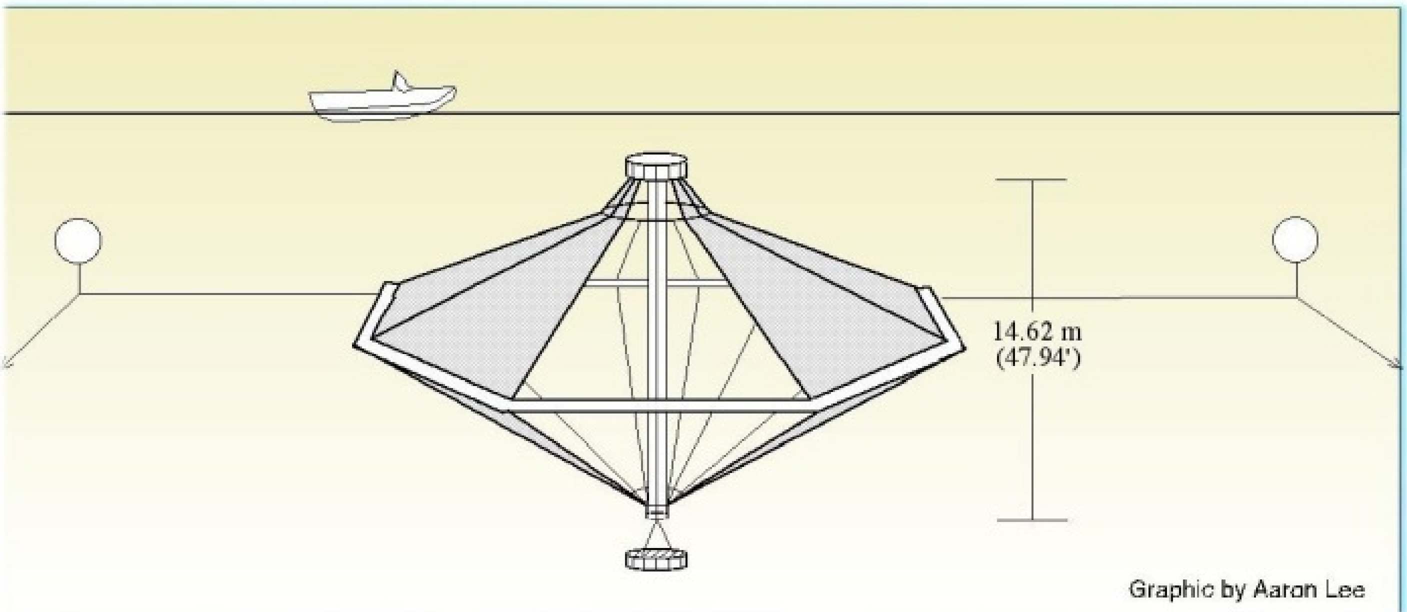
36. Mahnken, C. “The need for new legislation to permit commercial aquaculture in the EEZ,” speech at the Conference on Marine Aquaculture: Effects on the Alaska Fishing Industry, (November 17 2003)

37. “Magnuson-Stevens Fishery Conservation and Management Act” (Public Law 94-265), (October 11 1996)

38. Biliana Cicin-Sain, et al., “Development Of A Policy Framework For Offshore Marine Aquaculture In The 3-200 Mile U.S. Ocean Zone,” 146, (July 2001)

Appendix.

Figure 1. Diagram of typical offshore aquaculture finfish net pen designed by Ocean Spar Technologies



List of Acronyms

Full name	Acronym
Advanced Technology Program	ATP
Department of Commerce	DOC
Environmental Assessment	EA
Environmental Impact Statement	EIS
Exclusive Economic Zone	EEZ
Food and Drug Administration	FDA
Genetically Engineered	GE
National Aquaculture Act	NAA
National Environmental Policy Act	NEPA
National Marine Fisheries Service	NMFS
National Oceanic and Atmospheric Administration	NOAA
Non Governmental Organization	NGO
Open Ocean Aquaculture	OOA

Table 3. Common and Scientific Names of Species mentioned in the Text

Common Name	Latin Name
Finfish	
Amberjack	*Seriola sp.*
Atlantic cod	*Gadus morhua*
Atlantic halibut	*Hippoglossus hippoglossus*
Atlantic salmon	*Salmo salar*
Chum salmon	*Oncorhynchus keta*
Cobia	*Rachycentron canadum*
Florida pompano	*Trachinotus carolinus*
Mutton snapper	*Lutjanus analis*
Pacific threadfin	*Polydactylus approximans*
Pink salmon	*Oncorhynchus gorbuscha*
Red drum	*Sciaenops ocellatus*
Red snapper	*Lutjanus sp.*
Sockeye salmon	*Oncorhynchus nerka*
Summer flounder	*Paralichthys dentatus*
Zebra fish	*Danio rerio*
Shell fish	
Blue mussel	*Mytilus edulis*
Sea scallop	*Placopecten magellanicus*

Acknowledgements

Michael Black, Craig Culp, Niel Frazer, Phil Lansing, Ben Lilliston, Duncan Maclean, Jane McCloskey, John McManus, Mark Ritchie, Shelly Vendiola, John Volpe.