DEPARTMENT OF MARINE RESOURCES

Aquaculture Reports & Issue Papers

Maine Aquaculture Review - this is a pdf file and is about 1.5 MB

Green Slime - pdf (507.13KB)

Environmental Monitoring of Salmon Aquaculture - pdf (442.79KB)

Information Sheet on Finfish Aquaculture Therapeutant Use - pdf (110.65KB)

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DEPARTMENT OF MARINE RESOURCES

Environmental Research & Monitoring

The Department, in conjunction with the Department of Environmental Protection, administers the Finfish Aquaculture Monitoring Program, or what is called the FAMP. The FAMP is a comprehensive monitoring program for all finfish farms in the State. The FAMP collects data routinely from farms in order to ensure they are operating within acceptable environmental limits.

The FAMP includes a twice-yearly video survey of all active farms collected in the spring and fall that provides clear and timely information on benthic (bottom) conditions. As well, dissolved oxygen readings are collected at farms in late summer when water temperatures are highest to ensure there are not violations of water quality standards. Finally every other year, a benthic survey of organisms is conducted under farms to determine the abundance and diversity of animals is within acceptable limits.

In addition to the FAMP, the Department conducts and participates in research on the impacts of aquaculture. Past research has included assessments of fallowing, organic enrichment, nutrient modeling of embayments, antibiotic residues, and nutrient enrichment.

Some of the Department's work is available at this site as .pdf files.

PDF Files available on-line:

Sowles, J., L. Churchill, and W. Silvert. 1994. The effect of benthic carbon loading on the degradation of bottom conditions under farm sites, p. 31-46. In B.T. Hargrave [ed.]. Modelling Benthic Impacts of Organic Enrichment from Marine Aquaculture. Can. Tech. Rep. Fish. Aquat. Sci. 1949: xi + 125p. Click here to see .pdf file - Very big file - be patient downloading

Silvert, W. and J.Sowles. 1996. Modelling environmental impacts of marine aquaculture. J. Appl. Icthyolo. (12) 75-81. Click here to see .pdf file - Very big file - be patient downloading

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Maine Aquaculture Review

February 2003

MAINE AQUACULTURE REVIEW

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1.0 INTRODUCTION

1.1 BACKGROUND

Aquaculture began in Maine in the 1970s, with limited culture of mollusc and finfish. Atlantic salmon aquaculture grew and was well established in the 1980s. Over the past 12 years, the salmon farming industry has grown in Maine from 19 farms in 1990, producing 1.9m pounds (Parametrix 1990) to a production estimated at 12.54m pounds in 1992, with an estimated value of $37.5m. Maine's salmon industry in 1999 produced a estimated value of $64.1m (Goldburg et al. 2001). Currently, Atlantic salmon produce 96% of the revenue. In 2002, there were 1,203 acres of subtidal land leased for aquaculture: 44 lease sites for finfish (26 active, 750 acres); 80 lease sites for shellfish (445 acres) and one lease site for seaweed (7 acres, Fisk 2002). The latter is no longer in production (John Sowles, MDMR, personal communication).

Aquaculture monitoring in Maine initially occurred on a case-by-case basis with a focus on finfish. Site-specific monitoring plans were developed for each site by the Maine Department of Marine Resources (MDMR) and Department of Environmental Protection (MDEP) but responsibility for monitoring was that of the individual site operators. As monitoring reports were submitted, it soon became obvious that data collection quality and methodology were extremely variable. The result was that comparisons between sites and over time were not possible. To address the problem of inconsistent monitoring in 1991, a unified monitoring program was developed. The Maine Legislature created the Finfish Aquaculture Monitoring Program (FAMP), where the state became responsible for monitoring all the finfish sites. The program was funded by a 1-cent tax for each pound of salmon. The fee supported contracting with a single entity to conduct monitoring according to MDMR and MDEP protocols. Through this, the FAMP was able to provide consistency in review for all farms and instituted a quality assurance program.

The industry and husbandry practices have changed dramatically since the early 1990s and new issues have emerged. For example, wild Atlantic salmon were declared a federally listed endangered species in 2000 in rivers and streams from the lower Kennebec River north to the U.S.–Canada border. The rivers and streams include the Denny's, East Machias, Machias, Pleasant, Narraguagus, Ducktrap, and Sheepscot Rivers and Cove Brook. Concern has escalated over maintaining genetic integrity and health of wild salmon given possible contact with escaped farm-raised individuals, which could interbreed and transmit disease (Goldburg et al.2001). The increased density of farms and populations within farms increase the likelihood of disease such as the epidemic of infectious salmon anemia (ISA) in 2001 in Cobscook Bay (Bangor Daily News 2002). This latest epidemic forced the removal of all farmed salmon from Cobscook Bay in February 2002. The growth of the industry has resulted in increased numbers of facilities, creating conflicts with stakeholders that include the fishing community, coastal landowners, and recreational users. The increased number of facilities has also increased the number of interactions with seals (whose population has been steadily increasing) and other wildlife. A change in feeding technology, specifically the use of continuous feeding combined with a dry feed, has reduced the amount of excess feed and nutrient input.

1.2 SCOPE

Given the changing landscape and as has been done in the past, an interagency committee [U.S. Army Corps of Engineers (USCOE), U.S. Environmental Protection Agency (US EPA), U.S. Fish and Wildlife Service (USFWS), U.S. National Marine Fisheries Service (NMFS), Maine Department of Marine Resources (MDMR), Maine Department of Environmental Protection (MDEP), Maine Department of Inland Fisheries and Wildlife (MDIFW)] convened to review the existing monitoring program. The objective was "*to evaluate Maine's ability to assess severity and extent of effects of marine aquaculture on the natural environment, test the applicability of existing FAMP methods and to provide recommendations to the State on measures to improve environmental assessments.*"

In subsequent meetings of the Interagency Technical Committee, it became clear the scope of work that included finfish, shellfish and algae culture was too large. Accordingly, the committee agreed to narrow the scope of this review to the Finfish Aquaculture Monitoring Program. Furthermore, it was agreed that Endangered Species Issues would not be dealt with in this review.

The scope of our investigation had three components: literature review, existing monitoring data evaluation, and proposed monitoring program.

The literature review focused on three main themes — impacts, monitoring, and emerging issues. Current literature on the potential environmental impacts posed by finfish aquaculture was reviewed, along with management strategies utilized in other regions. Monitoring protocols and regulations developed elsewhere were evaluated in terms of Maine's unique marine environment and regulatory framework.

The monitoring program evaluation was subdivided into water quality issues and biological issues, primarily benthos. The main objectives were to evaluate Maine's ability to assess severity and extent of effects of marine aquaculture on the natural environment and to test the applicability of existing Finfish Aquaculture Monitoring Program (FAMP) methods. For water quality, the following questions were addressed:

- Does FAMP in its current form meet the requirements established by regulatory framework?
- As such, has FAMP provided data with which MDMR can adequately assess effects from aquaculture on the marine environment?
- Can FAMP provide data necessitated by current and future permit requirements?
- If not, but deemed necessary by MDMR, how can FAMP be modified to adequately address the current requirements and emerging water quality concerns?

Benthic monitoring evaluation asked the following questions:

- Do measured parameters allow an assessment of regulatory compliance (i.e., "no unreasonable impact"(based on best professional judgement) to the balanced indigenous benthic community)?
- Do video observations confirm conclusions based on measured parameters (both water quality and benthic) in terms of degree of impairment?

The proposed monitoring program incorporates results from the existing data evaluation to include variables that are best able to meet existing and future regulatory requirements. Lessons learned from monitoring programs from other states and provinces were used to shape suggestions for FAMP.

2.0 LITERATURE REVIEW

2.1 REGULATORY REVIEW

Aquaculture is regulated by a number of federal and state regulations as listed in Table 2-1.

TABLE 2-1. FEDERAL AND STATE REGULATIONS GOVERNING MARINE AND ESTUARINE AQUACULTURE FACILITIES

Regulation	Jurisdiction	Description
Section 402, Federal Water Pollution Control Act (33 U.S.C. 402)	US EPA , delegation to MDEP	NPDES permits
Section 403, Federal Water Pollution Control Act (33 U.S.C. 403)	US EPA	Ocean Disposal Criteria
Section 103, Marine Protection Research and Sanctuaries Act (16 U.S.C. 1431).	USCOE	Disposal of dredged material in ocean waters
Section 404, Clean Water Act (33 U.S.C. 404)	USCOE	Fill in waters in the United States
Rivers and Harbors Act of 1899 (33 U.S.C. 403)	US ACOE	Governs structures in navigable waters
The Migratory Bird Treaty Act (16 U.S.C. 703 *et seq.*)	USFWS	Depredation permit required to kill protected species
Endangered Species Act 16 U.S.C. 1531 *et seq.*	USFWS/NMFS	Protects federally listed species and their habitats
Marine Mammal Protection Act (16 U.S.C. 1361 *et seq.*)	NMFS	Protects marine mammals
Magnuson Stevens Fishery Conservation and Management Act (16 U.S.C. 1801 *et seq*)	NOAA	Governs Essential Fish Habitat
Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C. 136 *et seq.*)	US EPA	Pesticide control
The Food, Drug, and Cosmetic Act (21 U.S.C. 301 *et seq.*)	Food and Drug Administration	Drug approval program
Water Classification Program 38 M.R.S.A., Article 4-A	MDEP	Establishes water quality standards for receiving waters
Subtidal Lands Lease for Aquaculture	MDMR	Includes both siting and monitoring

Discharges from "point sources" are regulated by the EPA under its National Pollution Discharge Elimination System permitting process. This process has been the cause of some debate, as virtually all facilities applied to US EPA Region I for NPDES permits but their applications were not processed. In January 2001, the Maine Department of Environmental Protection was delegated authority to issue NPDES permits. MDEP is in the process of developing an aquaculture general permit that could cover many of the State's existing and new aquaculture facilities to bring them into compliance with federal statutes. Adjudicatory hearings will be held by the Maine Board of Environmental Protection early in 2003.

In February 2001 US EPA granted a water quality permit to the Acadia Aquaculture net pen fish farm to operate in Blue Hill Bay (EPA 2001). Because some of the conditions were economically unfeasible, the applicant refused the permit and the lease voluntarily terminated. It was, however, the first and only federal net pen permit issued to an aquaculture facility in Maine (although Washington State has issued permits for years and Maine DEP issued permits prior to 1989) and provided permit writers with a constructive exercise to address the difficult issues permitting a non-pipe discharge such as net pen aquaculture.

EPA's permit included numerous conditions and standards that would have:

- limited the total annual amount of fish feed that may be used at the site unless studies are completed to show that higher levels of nutrient addition can safely be allowed;
- required bottom monitoring with enforceable limits on conditions under and around the pens;
- required frequent water column monitoring with specific dissolved oxygen limits at the pen site;
- limited the use of fish medications;
- incorporated U.S. Fisheries and Wildlife Service recommendations for wild Atlantic salmon protection.

Since 1992, US EPA has been developing national effluent limitation guidelines and new source performance standards for concentrated aquatic animal production point source categories Draft guidelines were recently proposed (FR, 9/12/2002, pages 57871-57928). The focus of the proposed rules emphasized use of Best Management Practices, primarily feed monitoring systems. The review also acknowledge the difficulties in permitting net pen aquaculture as opposed to conventional pipe discharges, especially regarding the site-specific and regional nature. One option, in fact the option preferred by the Joint Subcommittee on Aquaculture (JSA) is the "no rule" option in recognition of the strong regional differences and scientific uncertainty associated with net pen aquaculture discharges.

Section 404 of the Clean Water Act governs fill in waters of the United States, regulated by The US Army Corps of Engineers. The Corps is also responsible for regulating the placement of structures in navigable waters through the Section 10 permitting process of The Rivers and Harbors Act. Other statutes include the Migratory Bird Treaty, authorizing U.S. Fish and Wildlife Service (USFWS) to regulate the killing of protected birds. USFWS is also responsible for the protection of non-aquatic endangered species listed under the Endangered Species Act. USFWS shares this responsibility with National Marine Fisheries (NMFS), who has responsibility for aquatic species. NMFS also is responsible for the protection of marine mammals under the Marine Mammal Protection Act. Drugs administered to aquaculture species are regulated by the Food and Drug Administration. Pesticides are regulated by the EPA under the Federal Insecticide, Fungicide, and Rodenticide Act.

The Magnuson-Stevens Fishery Conservation and Management ("Magnuson") Act established fishery management plans for conservation and management of fishery resources and mandated that habitat identified as "essential fish habitat" ("EFH") for managed fish species for spawning, breeding, feeding, or growth be protected.

At the state level, aquaculture facilities require a lease from the Department of Marine Resources, which is responsible for processing the lease application and evaluating potential environmental effects. The lease application must characterize potential environmental impacts of the project, meeting the following standards:

1. Will not unreasonably interfere with the ingress and egress of riparian owners;
2. Will not unreasonably interfere with navigation;
3. Will not unreasonably interfere with fishing or other uses of the area taking into consideration the number and density of aquaculture leases in an area.
4. Will not unreasonably interfere with other aquaculture uses;
5. Will not unreasonably interfere with the ability of the lease site and surrounding areas to support existing ecologically significant flora and fauna;
6. The applicant has demonstrated that there is an available source of organisms to be cultured for the lease site; and
7. The lease does not unreasonably interfere with public use or enjoyment within 1,000 feet of municipally owned, state owned or federally owned beaches and parks or municipally owned, state owned or federally owned docking facilities.

Comments from state, federal and municipal agencies including Inland Fish and Wildlife, Bureau of Parks, Harbormasters, Department of Environmental Protection and others are submitted for consideration by MDMR.

Maine Department of Environmental Protection is responsible for ascertaining that any discharge will not violate state water quality standards. The FAMP was established in 1991 through collaboration with cooperating state and federal agencies (US EPA, USCOE, NMFS, USFWS, and MDEP. The Finfish Aquaculture Monitoring Program (FAMP) was specifically designed to provide information that could enable the MDEP and MDMR to determine whether a finfish facility meets the requirements of Maine's Water Quality Standards (38 M.R.S.A., Article 4-A, Water Classification Program, Waste Discharge Law 38 M.R.S.A. §413 (2-F)) and the Salmon Aquaculture Monitoring Law 12 M.R.S.A. §6078 (4). Under MDEP Title 38 (Water Classification Program), the standards for Class SB waters state: "Discharges to Class SB waters shall not cause adverse impact to estuarine and marine life in that the receiving waters shall be of sufficient quality to support all estuarine and marine species indigenous to the receiving water without detrimental changes in the resident biological community." FAMP monitoring has focused on "worst-case" time of year and was intended as a screening tool. If conditions under and around a farm warranted, additional sampling could be done to support an enforcement case. The FAMP also provides data for reviewing current environmental requirements and possible future modifications.

The FAMP has the following components:

- monthly confidential production reports from lease-holders
- Dissolved oxygen monitoring during the warmest part of the year and when fish biomass is highest, generally late August and September.
- Benthic video monitoring in spring and fall
- Biennial fall benthic infauna sampling

Monitoring is conducted by an independent contractor funded by the industry through a fee based on production.

2.2 LITERATURE REVIEW

Environmental impacts of net pen aquaculture have been extensively researched and documented.

2.2.1 Finfish Culture

Finfish net pen culture has significant differences from other forms of aquaculture such as shellfish or marine algae for several reasons. First, finfish are more intensively cultured in the sense that there is more biomass per unit area. Second, they require the addition of feed, which not only intensifies the effects of nutrient loading but also introduces potential contaminants. Nash (2001) reviewed impacts from salmon net-pen culture in the Pacific Northwest, categorizing them in terms of the level of risk (Table 2-2).

TABLE 2-2. SOURCES OF ENVIRONMENTAL RISK FROM SALMON NET CULTURE AND LEVEL OF PRESUMED RISK (SOURCE: NASH 2001)

Risk Level	Source
High	Deposition from feces and uneaten feed, leading to anoxic sediments and changes in benthic community structure
	Sediment accumulation of heavy metals and organics from anti-fouling compounds and fish feed
	Impacts from pharmaceuticals and pesticides on other species
Low	Effects of low oxygen, hydrogen sulfide, and ammonia on other species
	Toxic algae blooms resulting from nutrient enrichment
	Changes in the epifaunal community
	Proliferation of human, fish and shellfish pathogens in the aquatic environment; increased disease in wild fish
	Market displacement of wild salmon by farmed varieties
Little or none	Escape of non-native salmon, with resultant hybridization or colonization of native habitat
	Competition with or predation on native species for forage
	Introduction of exotic pathogens or contribution to the development of antibiotic-resistant bacteria
	Impacts on human health and safety from salmon consumption or working in/around facilities

Based on this list, benthic deposition of food and feces, with subsequent effects from increased organics and potential contaminants and toxics, have the highest likelihood of adverse effects on the environment. Impacts on water quality are considered to have less of an effect on the environment and primarily result from decreased dissolved oxygen and increased nitrogen concentrations. Fish farming contributes nutrients to the water column and underlying benthos in the form of fish waste and uneaten fish food. Older literature reports waste food on the order of 20-30% (Beveridge 1996) when the industry relied on moist food. More recent work in Maine suggests that, with the use of dry food, loss to the bottom averages less than 5% (Findlay and Watling 1995). Their work estimated that total proportion of labile organic carbon from feed that settles under net pens, combining both uneaten feed and salmon feces, is approximately 8.8%. Subsequent effects on the benthos and water column are summarized in Table 2-3. Feeding method and other husbandry practices can affect the amount of loss. The use of automatic feeding can increase the food loss; however, coupled with video monitoring, food loss can be minimized. Deposition of feed and feces beneath floating fish cages also vary, with local topographic and hydrographic conditions, in particular current and depth, which strongly affect the distribution and amount of material that reaches the sea floor (Weston 1986). These physical conditions along with standing stock on site impact on localized dissolved oxygen levels. It is estimated that 70% of nitrogen fed to fish is released as soluble ammonium (Gowen 1988).

TABLE 2-3. CHANGES TO THE BENTHOS AND WATER COLUMN ASSOCIATED WITH ORGANIC ENRICHMENT WITH ORGANIC WASTE FROM INTENSIVE FLOATING CAGE CULTURE (SOURCE: GOWEN ET AL.1990)

Effect	Type
Sediment Chemistry	Reduction in redox potential
	Increase in sedimentary carbon and nitrogen
	Methane, hydrogen sulfide production
	Enhanced remineralization of organic nitrogen
Biological	Growth of sulfur bacteria (e.g., *Beggiatoa*)
	Reduction in macrofauna biomass, abundance, and species composition
	Increase in biomass of opportunistic species (e.g., *Capitella capitata*)
Water Column	Eutrophication and hypernutrification
	Reduction in dissolved oxygen (respiration and BOD)

One of the most important aspects in understanding, evaluating, and in turn monitoring the impacts of aquaculture is the question of scale. Aquaculture impacts may occur on a variety of spatial and temporal scales. Silvert (1992) categorized these as internal, local, and regional. Internal impacts are most closely associated with dissolved oxygen reduction due to respiration. This impact is observed within and in the immediate vicinity of the pens and over a relatively short time frame – minutes to hours. Local impacts most directly affect the benthos and the seafloor in the vicinity of the pens. Although the spatial scale of these impacts is similar to that of internal impacts, the temporal response of the benthos to organic loading is generally considered to occur over months to years. The effect of aquaculture on a regional level is often associated with conveyance of disease and impact on wild species (competition or genetically). These issues are not addressed directly by FAMP or this report, but one impact that is discussed relates to the impact of dissolved nutrients (including BOD) on the ecosystems of the bays and estuaries where the aquaculture facilities are located.

Many of the benthic impacts have been quantified from monitoring activities conducted in Maine and elsewhere in the world. However, these impacts represent discrete times, locations and operating conditions and cannot represent the full spectrum of impacts around aquaculture facilities. In an earlier outside review of the FAMP, Parametrix (1990), recommended that the State of Maine utilize modeling to answer siting questions and predictions of "dilution and dispersion" of facility byproducts. Researchers have turned to modeling in an effort to simulate a range of conditions, with an added benefit of predicting impacts for future or expanded facilities. Silvert (1992, 1994) and Gowen (1994) used particle settling principals to predict carbon loading, using the factors of the settling rate of the feed, current speed, and depth. Once deposited, the ambient benthic and epibenthic community determines the rate of carbon processing. Associated benthic effects are the result of a more complex process and are not as easily modeled. Here in Maine, Sowles et al. (1994) and Silvert and Sowles (1996) examined 23 salmon farms and found good agreement with carbon accumulation model results and an index of predicted benthic conditions. This enabled them to develop a predictive model that described levels of benthic impact based on quantity of fish on site, depth, and current velocities. These results can begin to address the more complex question of "carrying capacity" or holding capacity i.e. the number of fish that can be supported in a given water body while maintaining the environmental quality, both in the water column and benthos. Models developed to address these questions must integrate factors such as tidal flushing, runoff, and meteorological conditions. Preliminary results (Silvert 1994) are encouraging and the principals of fuzzy logic offer promise (Silvert 1997).

In addition to the organic loading associated with feed, constituents of feed may also be deposited in sediments from uneaten feed or feces. If present in sufficient quantities, there exists a potential ecological risk to benthic infauna. Salmon feed contains zinc as a mineral supplement. A study of 27 salmon farms in British Columbia (Brooks 2000a) found that exceedances of the aquatic effects threshold in 10% of the samples, with significant correlation between Total Volatile Solids (TVS) and sediment sulfides. Since toxicity is inversely related to AVS concentration, however, Brooks also concluded that "no effects should be anticipated from the observed concentrations of sediment zinc under salmon farms." His work also demonstrated the highly localized and rapidly returned to background levels once the farms were fallow. Concentrations of copper in sediments surrounding net pens have been shown to be elevated from use of antifouling paints and solutions. Brooks (2000b) found that sediment copper concentrations did not differ significantly among farms using Flexgard™-treated nets, farms with untreated nets, and reference sites. However, copper exceeded NOAA ER-M and Washington Sediment Quality criteria in 11% of sediment samples around 14 British Columbia farms Brooks found clear evidence that elevated copper was a result of net washing, which dislodges paint chips, rather than leaching or erosion. Thus, husbandry practices can help mitigate these effects.

Organic compounds also are present in salmon feed, with evidence of bioaccumulation in salmon flesh. Easton et al. (2002) found commercial feed contained PCBs, organochlorine pesticides, brominated diphenyl ethers, PAHs and dioxins. Studies in New Brunswick (Burridge et al, 1999) where tides are similar to Maine tides but with an industry twice as large and has operated for a longer period of time also show elevated levels of metals and organic compounds in the vicinity of pens but the levels were not sufficient to suggest toxicity. The presence of contaminants in sediments around salmon pens and the potential for ecological risk has been initiated in 2001 here in Maine (John Sowles, MDMR, personal communication).

Net-pens and associated moorings can cause disturbance to the underlying substrate and associated benthic organisms. Net cleaning can also cause bottom disturbance and additionally result in deposition of formerly attached epiphytic organisms such as algae and blue mussels (Silvert and Sowles 1996). Potential benefits from fouling organisms on nets, removing particulates from the water column, have not been quantified.

Aquaculture activities can have both direct and indirect effects on water quality. The most obvious direct impact is a direct and immediate decrease in dissolved oxygen concentration due to fish respiration. The magnitude of the decrease is related to a variety of factors including biomass, pen configuration, current velocity, and topography. In Puget Sound, dissolved oxygen reductions of up to 2 mg/L in water passing through aquaculture pens have been observed although in most cases the decrease is ≤0.5 mg/L (Nash 2001). The sensitivity of salmonids to lower oxygen levels (6 mg/L considered a minimum for optimal health, Nash 2001) provides a direct incentive for minimizing this impact either by site location or reductions in stocking. Indirect impacts are related to inputs and distribution of nutrients and organic matter (primarily dissolved, but also small suspended particulates) into the surrounding waters. Nutrients, specifically nitrogen, have a secondary effect associated with the potential increase in primary production and phytoplankton with a worst case scenario resulting in harmful algal blooms The dissolved and suspended organic matter ultimately contributes to the BOD of the system. It has been suggested by many scientists that these indirect effects on water quality should be evaluated using a modeling approach to understand the assimilative capacity of the embayment where current or proposed aquaculture sites reside.

Food web effects can extend beyond water quality and benthic effects. The aggregation of fish can attract and entangle predators that include seals, birds and other species. Facility activities can increase noise and light, potentially disturbing nesting marine birds. The effects of aquaculture on shorebirds in Maine does not appear to be a large concern, especially since there is a 0.25-mile limit around identified nesting areas. However, impacts on aquaculture have not been quantified nor has the sufficiency of the 0.25-mile limit been tested (Steve Timpano, MDIFW, personal communication). Predation by marine mammals has also been an issue. Anecdotal evidence indicates there is a large variation in seal predation and associated damages at finfish facilities in Maine. An ongoing investigation is looking at these interactions/predation events and determining factors that influence predation frequency and levels at finfish farms including: proximity to seal haul-outs, husbandry practices, and use of predator-deterrents. Anecdotal evidence from Maine salmon farmers points to husbandry practices as a major contributing factor to predation occurrences, i.e., cleaning of mortalities on a regular basis. Others have indicated that "acoustic harassment devices" have limited effectiveness and that seals habituate to them. It is in the Industry's best interest to minimize these interactions, and it is currently making use of a variety of tools to keep reduce them (Marcy Nelson, University of Maine, personal communication.). Studies at salmon farms in New Zealand have found a correlation between predation and proximity to Australian fur seal haul-outs (Pemberton and Shaughnessey 1993).Pemberton and Shaughnessy (1993) found that the frequency of predation on fish-farms in Tasmania increased with decreasing proximities from Australian fur seal (*Arctocephalus pusillus doriferus*) haul-out sites.

3.0 EXISTING MONITORING DATA REVIEW

3.1 WATER QUALITY

3.1.1 FAMP Sampling Protocols

The main focus of FAMP as it relates to water quality is on the measurement of dissolved oxygen. Additional *in situ* data are collected for pressure (depth), temperature, salinity, and pH. Percent saturation is also calculated based on dissolved oxygen concentration and ambient temperature and salinity. Details on the use and calibration of the instruments are provided in Heinig 2000a. This data review focuses on the dissolved oxygen concentration and percent saturation data.

The original monitoring protocol developed in 1991 called for semimonthly sampling of dissolved oxygen by the operators at each lease site July, August and September. Additional oxygen profile measurements were made annually in August at three stations upstream, in the vicinity and downstream of the sites in August. As might be expected, the data from the initial efforts in 1992 and 1993 was 'sporadic and of questionable quality' (Heinig 2000a). To reduce data variability and increase reliability, MDMR and MDEP restructured the program in 1994 and hired a single contractor to make the measurements at all lease sites. From 1994 to 2002 (excluding 1997 and 2000), annual measurements of these in situ parameters were made in September or October at stations 100 m upstream, 5 m downstream, and 100 m downstream of the pens. As the descriptions suggest, the stations are selected each year based on pen configuration and prevailing currents. Although this is a valid and reasonable sampling approach, it makes interannual and between site comparisons difficult to interpret. It should also be noted that sampling location and distances from sites/pens will be a critical factor in the development of both general and site-specific permit monitoring/compliance requirements.

3.1.2 Data Compilation

FAMP data are currently stored as individual Seabird output files or Lotus/Excel spreadsheets. Due to the major data management effort that loading all of the data into a database would entail, only a subset of the FAMP water quality data were used in this analysis. From the 35 sites listed in Table 3-1, eight sites were selected based on location to provide adequate geographical distribution (Table 3-2). A subset of four sites was selected for examination of interannual trends based on data availability. All temperature, salinity and dissolved oxygen profile data collected at these sites and years have been compiled in an MS Access database. The 1995 to 1999 data were converted directly from Seabird output files to MS Excel and imported, while 2001 data were available in MS Excel format. As the 2001 data were readily available all sites visited in that year have been added to the database and included in this evaluation. The additional 14 sites are also listed in Table 3-2 (Note that some of these sites do not appear in Table 3-1 as they are either new or the names have changed). Data from the two primary control sites in Cobscook and Machias Bays were also loaded and included in the evaluation.

TABLE 3-1. SALMON FARMS, OWNERS, LOCATIONS, AND YEARS WHEN BENTHIC INFAUNA DATA WERE COLLECTED

Site Name	Owner	Location	Town	Depth*	Baseline (Year)	First year of benthics	1991	1992	1993	1994	1995	
ASMI CI	Atlantic Salmon of Me	Cross Island		50	NO	1992		FB		FB		FB
ASMI DI	Atlantic Salmon of Me	Dyer Is	Harrington	48	1994	1997						
ASMI FI	Atlantic Salmon of Me	Flint Is.	Harrington	39-47	1993	1995						FB
ASMI II	Atlantic Salmon of Me	Starboard Is	Machiasp.	**40-44**	1991-LIMITED	1994				FB		FB
ASMI LI	Atlantic Salmon of Me	Libby Is.	Machiasp.	54	1992	1994					FB	
ASMI ST	Atlantic Salmon of Me	Stone Is.	Machiasp.	45-50	1995	2000						
BPFI BE	Birch Point Fisheries	Birch Pt	Eastport	30-39	NO	1993					FB	
CONA BC	Connors Aquaculture	Broad Cove	Eastport	50	NO	1992		FB		FB		FB
CONA CP1	Connors Aquaculture	Comstock Pt	Lubec	50	NO	1992 - as CONA CP				FB		FB AS CP
CONA CP2	Connors Aquaculture	Comstock Pt	Lubec	39-48	1989-LIMITED	1992 - as CONA CP				FB		FB AS CP
CONA DC	Connors Aquaculture	Deep Cove	Eastport	41	NO	1992				FB		FB
CONA SB	Connors Aquaculture	South Bay, Sw Gove pt	Lubec	55	NO	1995					FB	
DESC GN1	D E Salmon Co.	Gove Pt.		25	NO	1992 as NESC GN		FB		FB		FB AS GN
DESC GN2	D E Salmon Co.	Gove Pt.	Lubec	72	1994	1992 as NESC GN						FB AS G
DESC LU	D E Salmon Co.	Johnson Bay	Lubec	**41-45**	1991-LIMITED	1995 as STEV LU						I
IACO HS	Island Aquaculture	Harbor Is.	Swans Is.	55	1990 and 1993	1991 as MPLT TC then 1994 as IACO HS						FB
IACO TC	Island Aquaculture	Toothaker Cove	Swans Is.	47-50	1988-LIMITED	1992 as MPLT TC		FB		FB		FB
IAFI CL	Int'l Aqua Foods	Harris Cove	Eastport	48	NO	1993 as HANK CL			FB		FB	
IAFI HP	Int'l Aqua Foods	Harris Cove	Eastport	21-40	1994	1999 as MAFI HP						

TABLE 3-1. SALMON FARMS, OWNERS, LOCATIONS, AND YEARS WHEN BENTHIC INFAUNA DATA WERE COLLECTED (CONT'D)

Site Name	Owner	Location	Town	Depth*	Baseline (Year)	First year of benthics	1991	1992	1993	1994	1995	19
IAFI JK	Int'l Aqua Foods	Kendall Head, Johnsons Cove	Eastport	30	NO	1992 & 1994 as HARS JK then 1996 as HARS JK1	FB		FB	FB, JK2	FB	
IAFI PC	Int'l Aqua Foods	Prince Cove	Eastport	36	NO	1993 as ISSI PC then 1995 as MAFI PC		FB		FB		
LREN TE	L R Enterprise	Treats Is	Eastport	30	NO	1993 as ECFF TE then COOK TE		FB		FB		
MCNB SCN	Maine Coast Nordic	Sand Cove N	Beals	45	1995	2001						
MCNC CH	Maine Coast Nordic	Cutler Harbor	Cutler	25	NO	1993		FB		FB		FB
MCNC CN	Maine Coast Nordic	Little River	Cutler	**23-29**	1992	1993	Owner operated, low impacts despite shallow depth.					
MCNI CW	Maine Coast Nordic	Cutler Penn,W	Cutler	30	1991 (Intertide Corp.) - Bent. Inf. Not Analyzed	1995	Site abandoned			FB		
MCNI SI	Maine Coast Nordic	Spectacle Is	Beals	33	1991 (Intertide Corp.) - Bent. Inf. Not Analyzed	1993 as RLLT SI				FB		FB
SFML JB3	Stolt Farm	Johnson Bay	Lubec	27-40	1993	1992 as SFML JB		FB	FB	FB		**FB**
SFML RN	Stolt Farm	Rogers is	Lubec	35	NO	1993 as RISC RN				FB		FB
TIFI CC	Treats Island Fisheries	Comstock Cove	Lubec	30	NO	1992 as NBFI CC		FB	FB			
TIFI JC	Treats Island Fisheries		JC		NO	1992 as NBFI JC		FB	FB		FB	
TIFI TW1	Treats Island Fisheries	Treats Is	Eastport	35	NO	1993 combined with TIFI TW2 as TIFI TW				FB		
TIFI TW2	Treats Island Fisheries	Treats Is	Eastport	35	NO	1993 combined with TIFI TW1 as TIFI TW						
TISF HT	Treats Island Fisheries	Hardwood Is/Trumpet	Blue Hill	108-180	1992	1994	A lot of impact downcurrent to south				FB	

*Sites that have been transferred to new leaseholders in the past will likely have different acronyms. The last two/three letters (depicting site location) of a given acronyı leaseholder.

*The majority of baselines from 1992-present were performed by MER Assessment Corp.

Depth is very approximate, gleaned from site maps. FB= FALL BENTHOS. S=SPRING VIDEO SURVEY

TABLE 3-2. LEASE SITES AND YEARS SELECTED FOR WATER QUALITY EVALUATION

Site	Location	Town	Years
ASMI CI	Cross Island	Machiasport	95, 96, 98, 99, 01
BPFI BE	Birch Point	Eastport	95, 96, 98, 99, 01
CONA BC	Broad Cove	Eastport	99, 01
CONA SB	South Bay/Gove Pt.	Lubec	95, 96, 98, 99, 01
IAFI PC	Prince Cove	Eastport	99, 01
MCNC CH	Cutler Harbor	Cutler	99, 01
SFML JB3	Johnson Bay	Lubec	99, 01
TISF HT	Hardwood Is	Blue Hill	95, 96, 98, 99, 01
Control 1	Birch Pt./Gove Pt.	Eastport	95, 96, 98, 99
Control 2	Chance Is/Point Ruth	Machiasport	96, 98, 99, 01
ASMI CC	Cooper's Ledge	Lubec	01
CONA CP	Comstock Point	Lubec	01
CONA DC	Deep Cove	Eastport	01
IACO BL	Black Island		01
IACO HS	Harbor Scragg	Swans Is.	01
IACO TC	Toothaker Cove	Swans Is.	01
IAFI HP	Harris Point	Eastport	01
IAFI JK	Johnson Cove/Kendall Head	Eastport	01
MCNB SI	Sand Island		01
MCNB SCN	Sand Cove North	Beals	01
MCNC CN	Cutler North	Cutler	01
MESI SH	Shackford Head		01
SFML RN	Roger's North	Lubec	01
SFML RS	Roger's South	Lubec	01

Objectives and Analytical Approach

As stated in the introduction, the objective of this project is to evaluate MDMR's ability to assess the severity and extent of effects of marine aquaculture on the natural environment based on FAMP data and to test the applicability of existing FAMP methods. Numerous data analyses to date have indicated that dissolved oxygen levels are normally well above state standards and during those instances when percent saturation levels are below the 85% standard, they are only slightly lower than the standard and usually only at a limited set of depths that are sampled (Heinig 2000a and references therein). Additionally, the dissolved oxygen concentrations are well above levels that might cause adverse biological effects. One of the goals of the evaluation is to determine if these results are representative of conditions or, in fact, a function of the sampling methodology used by FAMP. This analysis focuses on the frequency and timing of measurements, the parameters measured and the spatial extent of measurements.