

# Marine Science Review - 224

## Aquaculture and hatcheries

### In this review:

- A. Recent articles – no abstract available
- B. Recent publications available online
- C. Recent articles with abstracts

## A. Recent articles – no abstract available

---

Cognetti, G., Maltagliati, F., and Saroglia, M. **The risk of "genetic pollution" in Mediterranean fish populations related to aquaculture activities.** *Marine Pollution Bulletin* 52(11): 1321-1323, 2006.

Cabello, F.C. **Salmon aquaculture and transmission of the fish tapeworm.** *Emerging Infectious Diseases* 13(1): 169-171, 2007.

## B. Recent publications available online

---

Marine Aquaculture Task Force. 2007. **Sustainable Marine Aquaculture: Fulfilling the Promise; Managing the Risks.** Marine Aquaculture Task Force, Takoma Park, MD. 128pp.

### **Available at:**

[http://www.whoi.edu/cms/files/mcarlowicz/2007/1/Sustainable\\_Marine\\_Aquaculture\\_final\\_1\\_02\\_07\\_17244.pdf](http://www.whoi.edu/cms/files/mcarlowicz/2007/1/Sustainable_Marine_Aquaculture_final_1_02_07_17244.pdf)

**Notes:** The Marine Aquaculture Task Force – an independent panel of leaders from scientific, policymaking, business, and conservation institutions – was charged with examining the risks and benefits of marine aquaculture in the U.S. and for developing a set of national policy recommendations to guide future development of the nation’s oceans. Among their conclusions were that Congress should enact legislation to ensure that strong environmental standards are in place to regulate the siting and conduct of offshore marine aquaculture and that the federal government should provide funding and incentives for research, development, and deployment of technologies, and techniques for sustainable marine aquaculture. Noting that marine aquaculture would benefit from clear federal leadership, the task force also recommended that Congress should assign a leading role to the National Oceanic and Atmospheric Administration for planning and regulating the industry. Furthermore, the task force concluded that: the permitting and application processes should be streamlined and simplified; there should be market-based incentives for businesses to invest in sustainable, ecologically sound fish-farming projects; and that environmental risks should be evaluated and best practices should be in place *before* permits are granted. In sum, the federal marine aquaculture program should be “precautionary, science-based, socially and economically compatible with affected coastal communities, transparent in decision making.”

-----

Butterworth, K.G., Cubitt, K.F., Finstad, B. and McKinley, R.S. 2006. **Sea Lice: The Science Behind the Hype.** Fraser Institute, Vancouver, BC. 23pp.

**Available at:** <http://www.fraserinstitute.ca/admin/books/files/Sea%20lice2.pdf>

**Notes:** Sea lice infestations are one of the most widely publicized issues regarding farmed fish in British Columbia. These small invertebrates have starred in documentaries, an advertising campaign, and even a popular US television show. But do these small parasites warrant all this attention? Current research reveals that Pacific salmon are less susceptible and more resilient to sea lice than Atlantic salmon. Furthermore, research into the actual effects of sea lice on Pacific Salmon is, as yet, inconclusive.

## C. Recent articles with abstracts

---

Bendell-Young, L.I. **Contrasting the community structure and select geochemical characteristics of three intertidal regions in relation to shellfish farming.** *Environmental Conservation* 33(1): 21-27, 2006.

**Notes:** Little is known about the impacts of intensive shellfish farming on intertidal ecosystems. To assess such impacts, several indices of ecosystem structure and select geochemical characteristics were contrasted among three intertidal regions, which represented a gradient of shellfish farming activities, namely (1) no active aquaculture, (2) actively farmed for three years and (3) actively farmed for five years. All three intertidal regions were located in Baynes Sound (British Columbia, Canada) and were geographically similar. Among the three beaches, species richness, community composition, bivalve abundance, biomass, distribution, and composition and surficial sediment per cent organic matter (carbon) and silt were compared. The intertidal regions that had been used for farming for three and five years had lower species richness, different bivalve composition, abundance and distributions, and a foreshore community dominated by bivalves, as compared to the intertidal region where no active farming occurred. Beaches that were actively farmed also had greater accumulations of organic matter and silt. Simplification of the intertidal benthic community, coupled with accumulations of organic matter and increased siltation, may have altered the ecology of the foreshore region used for intense shellfish harvesting. To access the foreshore for shellfish farming in a sustainable manner, studies are needed to determine the scale to which intensive use of the foreshore for shellfish purposes alone is feasible without undue harm to the environment.

-----

Nagarajan, R. and Thiyagesan, K. **The effects of coastal shrimp farming on birds in Indian mangrove forests and tidal flats.** *Acta Zoologica Sinica* 52(Supplement): 541-548, 2006.

**Notes:** Large areas of mangroves in India are disappearing rapidly due to booming shrimp aquaculture along its coasts. Such losses, pollution and direct conflict with aquafarmers has resulted in a decline in the number and diversity of birds along the coastal wetlands of India. In the Pichavaram mangroves, species numbers have fallen from 30 in 1995 to 24 at present. At the Point Calimere sanctuary, the flamingo (*Phoenicopterus minor*) population has dropped from 20 000 to a mere 5 000 birds. The Sunderbans wilderness of West Bengal is being eroded by shrimp farms and its bird life is also declining. In brackish Pulicat Lake, north of Madras, the flamingo population has dropped from more than 10 000 to just 1 000 due to pollution of feeding grounds by shrimp farm effluents. In natural tidal flats on the Nagaiipattinam and Karaikal coasts, the waterbird population of 45 species averages 400 per tidal flat, while in the areas adjacent to shrimp farms, only 9 species of birds were recorded at an average of 80 birds per similarly sized area. Analysis of data from the Asian Midwinter Waterfowl Census over the past 10 years also reveals negative impacts on coastal bird life after aquaculture expansion. Guidelines for the construction of aquafarms by the National Environmental and Engineering Institute of India (NEERI) and Coastal Authority of India, and rulings from the Supreme Court of India, could form the basis for redressing such impacts.

-----

Chinabut, S., Somsiri, T., Limsuwan, C., and Lewis, S. **Problems associated with shellfish farming.** *Revue scientifique et technique de l'Office international des Epizooties* 25(2): 627-635, 2006.

**Notes:** Shellfish culture is a major sector of aquaculture production worldwide, and zoonoses and drug residues associated with shellfish farm practice are of concern to public health. This paper focuses on three of the most important shellfish species: molluscs, crabs and shrimp. Although many diseases can affect shellfish, they do not appear to be transmittable to humans. Rather, the main hazards are associated with the methods used to farm the different species. The risk to human health from shellfish most commonly relates to contamination by biotoxins produced by marine algae. Another well-recognised problem associated with shellfish culture is the contamination of shellfish with domestic sewage that contains

human pathogenic bacteria and viruses, which causes diseases such as typhoid fever and hepatitis. In shrimp farming, the main potential food safety hazards are zoonoses, chemical contamination and veterinary drug residues. Untreated effluent from shrimp farms is a major concern to the environmental sector as it is known to promote plankton blooms if directly discharged into natural water sources.

-----  
Frost, L.A., Evans, B.S., and Jerry, D.R. **Loss of genetic diversity due to hatchery culture practices in barramundi (*Lates calcarifer*).** *Aquaculture* 261(3): 1056-1064, 2006.

**Notes:** Many aquaculture hatchery practices are detrimental to the long-term viability of restocking and selective improvement programs. Small effective broodstock population sizes, differential broodstock contribution, differential larval/juvenile survival during metamorphosis and size-based grading, all have the potential to drastically reduce the level of genetic variation remaining in hatchery populations. Monitoring levels of genetic variation and maintaining detailed pedigrees on progeny is the key to circumventing these problems. In this study we used microsatellites, coupled with DNA parentage analyses, to track the loss of genetic diversity in two independent commercial barramundi (*Lates calcarifer*) hatcheries over three mass spawning events, where up to two females and seven males had the opportunity to participate. Initial broodstock contributions were observed to be highly skewed, with significant differences observed in both the level of contribution by females to each mass spawning, as well as in the number of males participating and subsequently contributing to the genetic composition of cohorts. Effective population sizes were around half that of census sizes. We then examined whether differential family survival through metamorphosis (27 days post-hatch) and/or first size grading further influenced the retention of genetic diversity levels initially sampled during spawning. Parentage analyses indicated that some families that had been initially represented in cohorts had been lost, or that the contribution by particular broodstock had changed. In one cohort, as many as 55% of progeny were found to be sired by a single male individual. Size grading was also found to potentially impact on genetic diversity, with data suggesting that family representation in each of the grades was non-uniform and that some families were on average faster or slower growing than others. These results illustrate that hatchery management practices have the potential to significantly impact on the retention of genetic diversity in this species.

-----  
Mente, E., Pierce, G.J., Santos, M.B., and Neofitou, C. **Effect of feed and feeding in the culture of salmonids on the marine aquatic environment: a synthesis for European aquaculture.** *Aquaculture International* 14(5): 499-522, 2006.

**Notes:** While marine aquaculture has grown rapidly, so have concerns regarding the environmental impacts caused by the industry. In particular, increasing discharges of solid and dissolved fish excretions, nutrients and therapeutic chemicals have coincided with greater public awareness of the possibility of environmental damage. This has stimulated a number of criticisms, drawn from a wide spectrum of interests, ranging from the use of natural fish stocks to produce fish meal for aqua feeds to the effects of enhanced nutrient input on the coastal marine environment. The present study reviews available information on the environmental effects of feeding practices in salmonid aquaculture in Europe. Accumulation of waste food and fish faecal material results in changes in the sediment under fish cages, characterized by a low redox potential, high content of organic material and accumulation of nitrogenous and phosphorous compounds. Although significant environmental impacts have been reported in the literature at distances of up to 100 m from the cages, in general such impacts are reported to be localized to within 20 - 50 m around the cages. For farmed salmon and trout, mass balance models have been developed for nitrogen and phosphorus, indicating that 50% of the nitrogen and 28% of the phosphorus supplied with the food is wasted in dissolved form. The maximum nutrient release can be estimated from the hydrographic conditions in the immediate vicinity of the farm, such as water volume, tidal water exchange and currents. At present production levels, improvements in the feeding efficiency and feed quality of aquafeeds could reduce waste and consequent environmental impacts.

-----  
McDaniels, T.L., Keen, P.L., and Dowlatabadi, H. **Expert judgments regarding risks associated with salmon aquaculture practices in British Columbia.** *Journal of Risk Research* 9(7): 775-800, 2006.

**Notes:** Making sound decisions about managing ecological risks necessarily involves relying on judgments by technical specialists informed by the best available scientific evidence. Yet, organizing those judgments in ways to assess the relative risks of different components of a technology, and considering priorities in managing those risks, is a difficult and under-

explored aspect of environmental management. In this study, we elicited the judgments of scientists associated with the salmon aquaculture industry in British Columbia in order to learn their expert viewpoints of potential risks. This paper presents survey results regarding structured judgments provided by scientists engaged in studies associated with aquaculture or preserving wild stocks of Pacific salmon species. There were statistically significant differences regarding judgments of the risks of various current aquaculture practices on wild salmon stocks. It was possible to rank the means of scientific judgment scores to prioritize these risks. Differences in rankings were location and context specific.

-----

Stickney, R.R., Costa-Pierce, B., Baltz, D.M., Drawbridge, M., Grimes, C., Phillips, S., and Swann, D.L. **Toward sustainable open ocean aquaculture in the United States.** *Fisheries* 31(12): 607-610, 2006.

**Notes:** In response to a request by American Fisheries Society President Christopher Kohler, we examined the current status of open ocean aquaculture in the Exclusive Economic Zone (EEZ) of the United States, interest in open ocean aquaculture activities, the regulatory environment, and the potential for sustainable development. There is currently little interest in establishing facilities within the EEZ by the commercial sector, largely because of the lack of a formal regulatory structure, though that may be changing as Congress develops legislation on aquaculture in the EEZ. Current U.S. open ocean research and commercial activities are in state or territorial waters. The National Oceanic and Atmospheric Administration is poised to take the primary regulatory lead in the EEZ, with other federal agencies, such as the Minerals Management Service, Army Corps of Engineers, and Environmental Protection Agency participating. Under proposed legislation, coastal states would have the opportunity to comment on facilities in the EEZ adjacent to their jurisdictions. A variety of concerns pertaining to open ocean aquaculture development have been put forward that relate to environmental sustainability. We conclude that in the absence of large-scale facilities in the EEZ and associated research in conjunction with such facilities, the potential risks of open ocean aquaculture cannot be adequately evaluated. Data obtained from open ocean sites in other countries may or may not be applicable in this country's EEZ, but international cooperation in sharing environmental information from open ocean aquaculture operations can help researchers and regulators develop environmental safeguards and have them in place, if and when open ocean aquaculture becomes a commercial reality in the United States.

-----

Pergent-Martini, C., Boudouresque, C.F., Pasqualini, V., and Pergent, G. **Impact of fish farming facilities on *Posidonia oceanica* meadows: a review.** *Marine Ecology: An Evolutionary Perspective* 27(4): 310-319, 2006.

**Notes:** The impact of fish farming facilities on *Posidonia oceanica* meadows was assessed from studies of intensive facilities carried out over the last few years. The disturbances caused by these fish farms were measured by means of both abiotic (light, sediment, interstitial water) and biotic variables (meadow density, leaf biometry, lepidochronology, primary production, epiphytes, reserve carbohydrates in the rhizomes), in function of increasing distance from cages and/or inside a geographically close reference site. The results showed significant degradation of these seagrass meadows in all the sectors investigated. When fish farming cages were placed above a *P. oceanica* bed, the meadow was severely degraded or disappeared and the sediment showed a strong increase in organic matter that could lead to anoxia phenomena. The irreversible impact of fish farming projects on *P. oceanica* meadows requires the application of the precautionary principle. Several recommendations (site selection, preliminary studies and monitoring over time) are suggested in order to enable piscicultural activities to be incorporated in a global process of Integrated Coastal Zone Management.

-----

Saksida, S., Constantine, J., Karreman, G.A., and Donald, A. **Evaluation of sea lice abundance levels on farmed Atlantic salmon (*Salmo salar* L.) located in the Broughton Archipelago of British Columbia from 2003 to 2005.** *Aquaculture Research* 38(3): 219-231, 2007.

**Notes:** Salmon farming began in British Columbia (BC) in the 1970s and in 2006, aquaculture represented BC's largest agricultural export. Along with this growth in production has been a growth in controversy, including the concern that sea lice originating from Atlantic salmon farms negatively impact wild juvenile pink salmon in the Broughton Archipelago. To understand the dynamic interaction between wild and farmed fish, data for on-farm abundance of sea lice are required. In this study, 33 000 Atlantic salmon from 20 active farms were examined over 3 years. Two species of lice were found: *Lepeophtheirus salmonis* and *Caligus clemensi*. Inter-annual and seasonal variations in abundance levels occurred with lower levels of *L. salmonis* in 2003 compared with 2004 and 2005, while *C. clemensi* levels were highest in 2003. The abundance of *L. salmonis* was greater on

older farmed fish. The findings are compared with European and eastern Canadian sea lice reports, and possible sources of sea lice on farmed salmon are discussed.

-----  
Rasmussen, R.S. and Morrissey, M.T. **Biotechnology in aquaculture: Transgenics and polyploidy.** *Comprehensive Reviews in Food Science and Food Safety* 6(1): 2-16, 2007.

**Notes:** Although capture fisheries have experienced slow to stagnant growth in recent years, the world population has been increasing, with subsequent rises in demands for marine-based foods. One possibility for alleviating potential food shortages and price increases is through aquaculture, which has experienced rapid worldwide expansion. A major focus of research in the aquaculture industry is on the use of biotechnology to increase food availability and reduce production costs, specifically through the manipulation of the genes and chromosomes of cultivated species. Examples include transgenic fish with properties such as increased growth rates, feed conversion efficiency, disease resistance, cold tolerance, and improved metabolism of land-based plants. However, use of transgenic organisms in aquaculture is a very controversial topic due to a number of environmental and human health concerns such as escapement and introduction of genetically modified organisms into the food chain. In response, some transgenic research has also been focused on inducing sterility to reduce the risk of transgenic organisms breeding with wild species. A method of chromosome manipulation, referred to as polyploidy, provides the option of creating sterile organisms, some of which also exhibit increased growth rates. This review paper will discuss recent advances in biotechnology research, specifically in regards to the manipulation of genes and chromosomes, for enhanced cultivation of fish and invertebrates. Major environmental and human health concerns will also be addressed.

-----  
Todd, C.D. **The copepod parasite (*Lepeophtheirus salmonis* (Krøyer), *Caligus elongatus* Nordmann) interactions between wild and farmed Atlantic salmon (*Salmo salar* L.) and wild sea trout (*Salmo trutta* L.): a mini review.** *Journal of Plankton Research* 29(Supplement 1): 61-71, 2007.

**Notes:** Ectoparasitic copepods are major pathogens of farm and wild salmonids throughout the North Atlantic. Since the early 1990s there has been controversy regarding the extent to which infective larvae of *Lepeophtheirus salmonis* originate from aquaculture sites and impact wild salmon (*Salmo salar*) and sea trout (*Salmo trutta*). Because of the impracticality of tracking individual planktonic larvae from hatching to final host colonization, reliance has been placed on non-genetic and genetic experimental approaches. Microsatellite analyses show that *L. salmonis* comprises a single panmictic population throughout the Atlantic; gene flow between parasites on wild and farmed hosts is sufficiently high to prevent population genetic differentiation by random drift. However, because of this lack of significant differentiation, no estimates of the levels of gene flow between farm and wild are possible. The possible evolution of resistance to chemotherapeutants by caligids is of especial concern to the aquaculture industry. Decreased efficacy has been reported for numerous compounds and identification of a point mutation of a sodium channel gene might be indicative of knockdown resistance to pyrethroids. An additional concern is that the more host generalist *C. elongatus* might become an especially severe pathogen to both salmonid and gadid host populations as the emerging cod (*Gadus morhua*) aquaculture industry develops.

-----  
Standal, D. and Utne, I.B. **Can cod farming affect cod fishing? A system evaluation of sustainability.** *Marine Policy* 31(4): 527-534, 2007.

**Notes:** The cod resources in the Barents Sea constitute the most important fisheries in Norway. In order to reduce resource allocation conflicts among different gear and vessel groups and to ensure profit for all participants throughout the value chain, the sector is thoroughly organized. The institutions established to ensure long-term sustainability, have been developed within the framework of a joint Norwegian-Russian fisheries management regime. However, due to a very high fishing mortality, the cod stock is now under severe pressure. In addition, a major part of the cod fisheries is highly seasonal and unable to be a stable supplier to neither the land-based industry nor demanding international markets. In parallel, cod farming is expected to become a new emerging industry, with potential to copy the success of farmed Atlantic salmon. Many actors within the cod fisheries fear the future competition from the growing cod farming sector. With reference to important attributes that characterize the cod fisheries and cod farming, this paper discusses how a future farming industry may affect the traditional cod fisheries. Moreover, we discuss how the fisheries may be forced to organize in the future to encounter the expected competition from cod farming.

---

Stottrup, J.G. and Sparrevojn, C.R. **Can stock enhancement enhance stocks?** *Journal of Sea Research* 57(2-3): 104-113, 2007.

**Notes:** Successful stock enhancement or restocking requires a thorough understanding of the ecological processes that provide a potential for stocking within different ecosystems, i.e. determine which factors define the potential for stocking, such as population dynamics, economic cost-benefits, fisheries management and socio-economic impacts. Stocking is not simply a question of aquaculture logistics (i.e. the ability to produce a sufficient number of fry relative to the magnitude of the natural recruitment within the system), nor should it be a new outlet for aquaculture production. Quantitative targets should be set and the expected performance of the stocking tested. Potential loopholes, such as post-release mortality and habitat requirements related to the release, should be examined and resolved. If properly managed, stocking may lead to an increase in population, contribute to the local fishery and/or lead to an increase in the spawning stock biomass. The criteria for stocking are discussed in this paper using examples from flatfish and cod stocking programmes within specific ecosystems.

---

Hara, M. and Sekino, M. **Genetic differences between hatchery stocks and natural populations in Pacific abalone (*Haliotis discus*) estimated using microsatellite DNA markers.** *Marine Biotechnology* 9(1): 74-81, 2007.

**Notes:** Genetic variations within and between nine hatchery stocks and seven natural populations of abalone including Ezo-abalone (*Haliotis discus hannai*) and Kuro-abalone (*H. d. discus*) were assayed with nine microsatellite markers. Marked reductions of genetic variability in the hatchery stocks were recognized in the allelic diversity and mean heterozygosity compared with the natural populations. Thirteen of 16 significant HWE deviations in hatchery stocks revealed heterozygotes excess, while all natural populations did not show such a tendency. Highly significant  $F_{ST}$  values were observed for all cases between the hatchery stocks, and between the hatchery stocks and natural populations. Genetic distance ( $D_A$ ) between each hatchery stock and the geographically proximal population (mean  $\pm$  SD, 0.108  $\pm$  0.035) were similar to those estimated for between the natural Ezo-abalone and Kuro-abalone (0.101  $\pm$  0.021). The self-assignment test, which allocated individuals to their own stock with a high success rate, provided evidence of solid genetic differences among the nine hatchery stocks. These results suggests that the allelic composition and diversity in the natural populations was not necessarily reflected in the hatchery stocks owing to population bottleneck and genetic drift through seedling process, and thus the seedling and stocking practice of these hatchery stocks should take much notice of the results to conserve the genetic diversity of natural populations.

---

Ribeiro, S., Viddi, F.A., Cordeiro, J.K., and Freitas, T.R.O. **Fine-scale habitat selection of Chilean dolphins (*Cephalorhynchus eutropia*): interactions with aquaculture activities in southern Chiloe Island, Chile.** *Journal of the Marine Biological Association of the United Kingdom* 87(1): 119-128, 2007.

**Notes:** Fine-scale habitat selection of Chilean dolphins was studied between January and April 2002 through shore-based theodolite tracking in order to investigate the environmental and behavioural determinants of habitat use, and to evaluate the interactions between this, species and aquaculture activities in Yaldad Bay, southern Chile. During 293.5 h of effort, movement and habitat selection patterns of dolphins exhibited a significantly concentrated use of only 21% of the entire study area. Correspondence analysis showed that shallow waters (5-10 m), proximity to coast and rivers were the most significant environmental parameters determining finescale dolphin distribution patterns, with foraging the most frequently observed activity. Aquaculture activities in the area were observed to affect dolphin habitat use patterns by restricting space available for biologically important dolphin behaviours.

---

Orr, C. **Estimated sea louse egg production from Marine Harvest Canada farmed Atlantic salmon in the Broughton Archipelago, British Columbia, 2003-2004.** *North American Journal of Fisheries Management* 27(1): 187-197, 2007.

**Notes:** Recent infestations of sea lice *Lepeophtheirus salmonis* on wild juvenile pink salmon *Oncorhynchus gorbuscha* and subsequent declines in the number of returning adult pink salmon have raised concern for the health of wild fish relative to salmon farming activities in the Broughton Archipelago, British Columbia. I used available (but limited) industry data to estimate sea

louse egg production from Atlantic salmon *Salina salar* farmed by Stolt Sea Farm (now Marine Harvest Canada, Inc., Campbell River, British Columbia) in 2003 and 2004. The 12 active farms contained between 1 and 5 million Atlantic salmon during the 2 years and about 800,000 fewer mature salmon at the start of 2003 than in 2004. Sea louse egg production peaked during winter-spring in both years prior to the seaward migration period of the area's small and vulnerable juvenile pink salmon and chum salmon *O. keta*. Marine Harvest Canada salmon hosted over 6 million gravid sea lice that produced  $1.6 \times 10^9$  eggs during 2 weeks in the winter of 2003-2004. Only half as many eggs were produced from the fewer hosts present during this period in 2003. Sea lice on farmed fish were further reduced to near zero each year through multiple uses of emamectin benzoate (Slice). Fewer farmed Atlantic salmon and sea lice in 2003 coincided with lower abundance and prevalence of *L. salmonis* on juvenile pink salmon and chum salmon near farms. A recent agreement between industry and conservationists may help improve data quality, our understanding of the dynamics sea louse-salmon interactions, and our chances of conserving wild salmon.

-----

Zydelis, R., Esler, D., Boyd, W.S., Lacroix, D.L., and Kirk, M. **Habitat use by wintering surf and white-winged scoters: Effects of environmental attributes and shellfish aquaculture.** *Journal of Wildlife Management* 70(6): 1754-1762, 2006.

**Notes:** Shellfish aquaculture is an expanding industry in coastal British Columbia, Canada, and occurs in important wintering areas for surf scoters (*Melanitta perspicillata*) and white-winged scoters (*M. fusca*). We quantified habitat use by scoters in relation to natural environmental attributes and habitat modifications associated with shellfish aquaculture. We found that, despite the extensive clam and oyster farming in our study area, densities of wintering surf scoters and white-winged scoters were related primarily to natural environmental attributes, particularly intertidal area, clam density, and sediment type; shellfish aquaculture variables were generally poor predictors of bird densities. We conclude that current levels and forms of shellfish aquaculture in our study site were not an important determinant of scoter distribution and abundance, suggesting that winter scoter populations and the shellfish aquaculture industry may be mutually sustainable. We caution that intensification or further industrialization of shellfish aquaculture in British Columbia could eventually lead to detrimental effects if some threshold level of habitat modification is exceeded.

-----

Neori, A., Troell, M., Chopin, T., Yarish, C., Critchley, A., and Buschmann, A.H. **The need for a balanced ecosystem approach to blue revolution aquaculture.** *Environment* 49(3): 37-43, 2007.

**Notes:** Many marine fish stocks have collapsed, demand for seafood has been rising steadily, leading to the vast expansion of aquaculture. Mariculture, is the leading contender to supply the added food demand. This is termed the Blue Revolution approach, modernized mariculture that works with finfish in sea cages and shrimp in costal ponds. Improvements are needed in feed composition, farm management, species diversification and farm location.

-----

Gibbs, M.T. **Assessing the risk of an aquaculture development on shorebirds using a Bayesian belief model.** *Human and Ecological Risk Assessment* 13(1): 156-179, 2007.

**Notes:** One of the largest Ramsar-designated wetlands in New Zealand is located at Miranda, in the Hauraki Gulf, at the head of a large sheltered embayment (the Firth of Thames). The habitat is particularly significant in that it supports large populations of nationally important, and Arctic migratory, shorebirds. At present regulatory authorities are processing applications for a new marine farming region in the Firth and both regulators and stakeholders have expressed a desire to investigate possible interactions between the possible marine farms and the Ramsar wetland. The specific objective of this study was therefore to use existing information to investigate the risks of the possible aquaculture activities on the ability of the southern Firth habitats to support shorebirds. The study involved the development of a hazard assessment, and then investigating risk pathways through the use of a Bayesian network model, and a complex systems model. The hazard assessment identified multiple pathways through which the farms may interact with the wetland habitat; including through changes to primary productivity, detrital pathways and sediment dynamics. Furthermore, both the Bayesian network model and complex systems model suggested that the ability of the habitat to support shorebirds is nonlinearly dependent on both the habitat size, and quality; both of which could potentially be influenced by the establishment of the farms.

-----

Barry, T.K. and Van der Zwaag, D.L. **Preventing salmon escapes from aquaculture in Canada and the USA: Limited international coordinates, divergent regulatory currents and possible future courses.** *Review of European Community and International Environmental Law* 16(1): 58-75, 2007.

**Notes:** Following an introductory review of the continuing problem of salmon escaping from aquaculture operations along the Atlantic and Pacific coasts of North America, and the considerable uncertainties over ecological impacts, this article examines the law and policy context for preventing escapes from three perspectives. First, the limited guidance for addressing aquaculture escapes under existing global and regional agreements/arrangements is highlighted. Second, how Canada and the USA have sought to control escape events at national and provincial/State levels is summarized. Third, possible future courses are identified, which improve the way salmon escapes are addressed, with stronger regional responses suggested as most promising. Enhancing the North Atlantic Salmon Conservation Organization's role in preventing escapes and placing transboundary aquaculture issues on the agendas of North Pacific regional cooperative arrangements are the potential courses emphasized.

-----

Nowak, B.F. **Parasitic diseases in marine cage culture - An example of experimental evolution of parasites?** *International Journal of Parasitology* 37(6): 581-588, 2007.

**Notes:** Rapid development of fish culture in marine cages has been associated with an emergence of parasitic diseases. There is a general trend to an increase in infections with ectoparasites with direct life cycles and a reduced diversity of parasites in aquaculture. Some mariculture creates conditions that are similar to serial passage experiments, which are used to study adaptation during experimental evolution of pathogens. In particular, increased density of fish, repeated introduction of naive hosts, homogenous host populations, fast growth and a potential decrease in genetic diversity are attributes of both aquaculture and serial passage experiments. Some free-living organisms, for example *Neoparamoeba* spp. and *Uronema* spp. parasitise fish in culture, but have not been reported from wild populations. Farming fish in marine cages can increase the risk of outbreaks of parasitic diseases, including those caused by opportunistic parasites. However, aquaculture has the potential to control parasitic diseases through selective breeding, vaccination and general fish health management.

-----

Skladany, M., Clausen, R., and Belton, B. **Offshore aquaculture: The frontier of redefining oceanic property.** *Society and Natural Resources* 20(2): 169-176, 2007.

**Notes:** Over the past decade, offshore aquaculture has gained significant momentum as a global and, in particular, a U.S. seafood development strategy. Issues surrounding property rights, environmental impacts, and the social desirability of offshore aquaculture are inadequately addressed by policymakers and aquaculture specialists. This review essay describes offshore aquaculture's place in the development of industrial fish farming and the policy issues surrounding an emerging natural resource issue of public concern. The full development of offshore aquaculture rests on a key political-economic factor: the ability to allow *de facto* private ownership of federally held ocean waters and bottom lands. We address the political obstacles that face marine property transformation and the emerging public deliberation around the development of this global food industry.

-----

Grant, J., Bugden, G., Horne, E., Archambault, M.C., and Carreau, M. **Remote sensing of particle depletion by coastal suspension-feeders.** *Canadian Journal of Fisheries and Aquatic Sciences* 64(3): 387-390, 2007.

**Notes:** Marine bivalves have been designated ecosystem engineers owing to their capacity to control estuarine water quality, particle dynamics, and primary production. Globally, bivalves have higher production than any other cultured animal. Large populations of natural, invasive, and cultured bivalves are suggested to cause changes in coastal ecosystem function through suspension-feeding of particles and biodeposition of waste materials. Association of bivalves with particle depletion is a trophic tenet of coastal ecosystems, but there are no previous observations of this process except at small scales. Using airborne hyperspectral remote sensing, we show direct evidence of aquaculture impacts at the ecosystem scale (kilometres), documenting significant depletion of phytoplankton through a blue mussel (*Mytilus edulis*) farm in eastern Canada, compared with dispersion in circulation model results without mussels. Understanding of factors controlling primary production and

ecosystem processes in the coastal zone is critical in light of growing reliance on this region for development and resource extraction worldwide

-----  
Eklof, J.S., Henriksson, R., and Kautsky, N. **Effects of tropical open-water seaweed farming on seagrass ecosystem structure and function.** *Marine Ecology Progress Series* 325: 73-84, 2006.

**Notes:** Seaweed farming is often depicted as a sustainable form of aquaculture, but suspected habitat alterations and spread of algae outside farms have rendered speculations on the actual degree of sustainability. We conducted an experimental field study on Unguja Island (Zanzibar, Tanzania) to investigate the effects of off-bottom seaweed farming on a tropical seagrass ecosystem, using 1.5 x 2.5 m experimental farm plots. After 11 wk, above-ground seagrass biomass was 40% lower than in control plots, owing to a combination of lower shoot density, shoot length and leaf growth rate. Since the biomass was constant between Day 15 and 75 in the farm (F) treatment, but increased by 67 vs. 48 % in the 2 controls (control treatment [C] and stick-and-line control treatment [CSL]), the effect exerted by the farm was a lack of potential biomass increase rather than an actual decrease. The effect was transplanted to associated organisms both in terms of lower seagrass epiphyte cover and changes in the abundance of 2 dominating epifauna taxa (> 1 cm): sea urchins and sponges. Furthermore, the F treatment caused an accumulation of seagrass leaf litter, but did not affect sediment organic matter (SOM) content. The mechanisms behind these effects were not explicitly tested, but algal shading, emergence stress and mechanical abrasion were identified as likely contributors. Interestingly, the effects were largely restricted to 1 of the 2 seagrass species present, *Enhalus acoroides*, while the other, *Thalassia hemprichii*, remained more or less unaffected. This may be due to reduced interspecific competition or species-specific differences in morphology and stress tolerance, and could in the long-term have implications for (amongst others) associated fish communities. Although seaweed farming at the current level is less detrimental than, for example, intensive shrimp farming, and therefore should be seen as a strong option for future aquaculture developments, intensive farming on seagrasses should be avoided or at least minimized by, for example, implementing other farming methods. The risk of ecosystem-level changes in large-scale and uncontrolled farm enterprises warrants a holistic and integrated coastal management approach which considers all aspects of the tropical seascape including human societies and natural resource use.

-----  
Hall-Spencer, J., White, N., Gillespie, E., Gillham, K., and Foggo, A. **Impact of fish farms on maerl beds in strongly tidal areas.** *Marine Ecology Progress Series* 326: 1-9, 2006.

**Notes:** In Scotland, Atlantic salmon *Salmo salar* cages are being moved out of areas with slow water movements, to disperse wastes and reduce impacts on benthic communities. This first study of the effects of fish farms on maerl beds (red algal coralline gravels of high conservation importance) demonstrated major impacts on the benthos, even in strongly tidal areas. SCUBA surveys of 3 fish farms located over maerl revealed a build-up of waste organic matter and 10 to 100-fold higher abundances of scavenging fauna (e.g. *Necora puber*, *Pagurus bernhardus*) than on 6 reference maerl beds. Visible waste was noted up to 100 m from cage edges, and all 3 farms caused significant reductions in live maerl cover, upon which this habitat depends. Near-cage infaunal samples showed significant reductions in biodiversity, with small Crustacea (ostracods, isopods, tanaids and cumaceans) being particularly impoverished in the vicinity of cages, and significant increases in the abundance of species tolerant of organic enrichment (e.g. *Capitella* spp. complex, *Ophryotrocha hartmanni*). Relocation of fish farms to areas with strong currents is unlikely to prevent detrimental effects to the structure and organisation of the benthos, and 'fallowing' (whereby sites are left unstocked for a period of time to allow benthic recovery) is inadvisable where slow-growing biogenic habitats such as maerl are concerned, as this may expand the area impacted.

-----  
Canty, M.N., Hagger, J.A., Moore, R.T.B., Cooper, L., and Galloway, T.S. **Sublethal impact of short term exposure to the organophosphate pesticide azamethiphos in the marine mollusc *Mytilus edulis*.** *Marine Pollution Bulletin* 54(4): 396-402, 2007.

**Notes:** Concern has been raised that the increased use of pesticides in intensive aquaculture practices may cause adverse sublethal effects to non-target aquatic species. Azamethiphos is an organophosphate (OP) pesticide used to combat sea lice infestations in farmed salmonids. Here, the sublethal impact on the blue mussel, *Mytilus edulis*, of short term exposure to azamethiphos was determined. The testing regime included biomarkers of exposure (acetylcholinesterase activity), cytotoxicity (neutral red retention), immune function (phagocytic index) and physiological condition (feeding rate). The distribution and

sensitivity of *M. edulis* acetylcholinesterase to inhibition by azamethiphos was first determined, yielding IC50 values of 0.736 and 1.30 mg l<sup>-1</sup> for gill and haemolymph, respectively. Exposure of mussels to 0.1 mg l<sup>-1</sup> azamethiphos for periods of up to 24 h caused a significant reduction in acetylcholinesterase activity in both the haemolymph (P < 0.0002) and the gill (P < 0.002), alteration in cell viability (P < 0.02) and decrease in phagocytic index (P < 0.03). The feeding rate remained unaffected. The results support the hypothesis that, in addition to its neurotoxic effects, azamethiphos can modulate haemocyte function and immune defence in *M. edulis* at environmentally relevant concentrations after only a few hours.

-----

Minchin, D. **Aquaculture and transport in a changing environment: Overlap and links in the spread of alien biota.** *Marine Pollution Bulletin* 55(7-9): 302-313, 2007.

**Notes:** Aquaculture has been practiced for some millennia. The speed and access of different transport modes in the spread of cultured species, their pests, parasites, diseases and associates, has changed over this time. There now exists an overlap and interlinking of different transport networks with further routes planned. Coupled with environmental changes and habitat alterations alien biota are presented with further opportunities to become more widely distributed. The certainty of the responsible pathway for the arrival of an alien species is not always easily deduced unless imported directly. A scheme for classifying different levels of certainty is proposed. Aquaculture itself consists of different cultivation intensities ranging from part to all of a species life-history and are classified accordingly in this account. It is inevitable that further species intended for cultivation will be utilized in different world regions and that other biota, some considered to be harmful, will also be transmitted. Nevertheless there are codes of practice such as those used by the IMO and ICES that can reduce some risks.

-----