

Marine Science Review – 400

Aquaculture and hatcheries

In this review:

- A. Recent articles – no abstract
- B. Recent articles with abstracts

O/A denotes an open access article or journal

A. Recent articles – no abstract

Stokstad, E. **Down on the shrimp farm.** *Science* 328(5985): 1504-1505, 2010.

B. Recent articles with abstracts

Lazard, J., Baruthio, A., Mathé, S., Rey-Valette, H., Chia, E., Clément, O., Aubin, J., Morissens, P., Mikolasek, O., Legendre, M., Levang, P., Blancheton, J.P., and René, F. **Aquaculture system diversity and sustainable development: fish farms and their representation.** *Aquatic Living Resources* 23(2): 187-198, 2010.

Notes: Initiatives for the sustainable development of aquaculture have so far focused on the production of codes of conduct, of best management practices, of standards etc., most of which have been developed by international organisations, the industrial sector and non governmental organisations. They were, to a large extent, produced using a "top down" process and inspired by models from intensive industrial shrimp and sea fish farming (mainly salmon). However, most of global aquaculture production comes from small-and medium-sized farms, essentially in Asia which contributes 92% of the total world aquaculture production volume. The objective of this article is to define the contours of systemic typologies that are able to express the sustainability conditions of aquaculture systems. The proposed approach builds on surveys of aquaculture systems which differ in terms of their biogeographical nature (temperate/tropical and north/south countries) or their farming techniques and their governance systems. This work is a prerequisite to any attempt at an individualised and comparative evaluation of specific aquaculture systems from either global or territorial viewpoints. In order to go beyond the cleavage of a typology based on the differentiation between developed and developing countries, three typologies were produced. These typologies allow for discriminatory variables to be identified such as for example the marketing methods or the pace of innovation: a structural typology, a functional typology and a systemic typology. Finally, the representations of aquaculture activity and of its sustainability that producers have of the 4 different types that emerge from the systemic typology were recorded and analyzed.

Bostock, J., McAndrew, B., Richards, R., Jauncey, K., Telfer, T., Lorenzen, K., Little, D., Ross, L., Handisyde, N., Gatward, I., and Corner, R. **Aquaculture: global status and trends.** *Philosophical Transactions of the Royal Society of London [B]* 365(1554): 2897-2912, 2010. **O/A**

Notes: Aquaculture contributed 43 per cent of aquatic animal food for human consumption in 2007 (e.g. fish, crustaceans and molluscs, but excluding mammals, reptiles and aquatic plants) and is expected to grow further to meet the future demand. It is very diverse and, contrary to many perceptions, dominated by shellfish and herbivorous and omnivorous pond fish either entirely or partly utilizing natural productivity. The rapid growth in the production of carnivorous species such as salmon,

shrimp and catfish has been driven by globalizing trade and favourable economics of larger scale intensive farming. Most aquaculture systems rely on low/uncosted environmental goods and services, so a critical issue for the future is whether these are brought into company accounts and the consequent effects this would have on production economics. Failing that, increased competition for natural resources will force governments to allocate strategically or leave the market to determine their use depending on activities that can extract the highest value. Further uncertainties include the impact of climate change, future fisheries supplies (for competition and feed supply), practical limits in terms of scale and in the economics of integration and the development and acceptability of new bio-engineering technologies. In the medium term, increased output is likely to require expansion in new environments, further intensification and efficiency gains for more sustainable and cost-effective production. The trend towards enhanced intensive systems with key monocultures remains strong and, at least for the foreseeable future, will be a significant contributor to future supplies. Dependence on external feeds (including fish), water and energy are key issues. Some new species will enter production and policies that support the reduction of resource footprints and improve integration could lead to new developments as well as reversing decline in some more traditional systems.

Rigos, G., Bitchava, K., and Nengas, I. **Antibacterial drugs in products originating from aquaculture: assessing the risks to public welfare.** *Mediterranean Marine Science* 11(1): 33-41, 2010. [O/A](#)

Notes: As aquaculture expands to meet human demand and compensate for pessimistic forecasts of fisheries catches, use of antibacterial agents to combat or forestall bacterial diseases is still a necessity, although effective vaccines and improved hygiene have aided drastically in this battle. The hazards for the consumer perspective arising from the imprudent use of such chemicals can be detrimental, especially if the residues persist above legal tolerance. These may include selection and dissemination of resistant bacteria, disruption of the colonization barrier in the human intestinal flora and allergic reactions. In cases that unlawful drugs reached the consumer via consumption of aquatic products, human health may be jeopardized even further. The present review article assesses these risks to human health.

Seyfried, E.E., Newton, R.J., Rubert, K.F., Pedersen, J.A., and McMahon, K.D. **Occurrence of tetracycline resistance genes in aquaculture facilities with varying use of oxytetracycline.** *Microbial Ecology* 59(4): 799-807, 2010.

Notes: The contribution of human activities to environmental reservoirs of antibiotic resistance is poorly understood. The purpose of this study was to determine if oxytetracycline (OTC) use in aquaculture facilities increased the detection frequency (i.e., prevalence) of tetracycline resistance (tet^R) genes relative to facilities with no recent OTC treatment. We used polymerase chain reaction to screen water and sediment from four noncommercial fish farms in northwestern Wisconsin for the presence of ten tet^R determinants: $tet(A)$, $tet(B)$, $tet(D)$, $tet(E)$, $tet(G)$, $tet(M)$, $tet(O)$, $tet(Q)$, $tet(S)$, and $tet(W)$. Water from farms with recent OTC use had significantly higher tet^R detection frequencies than did water from farms without recent OTC use, with prevalence in raceways and rearing ponds of farms with recent OTC use exceeding by more than twofold that of farms not using OTC. Effluent from all farms, regardless of treatment regime, had higher tet^R detection frequencies than their corresponding influent for all genes, but the specific combinations of tet^R genes detected in a sample were not different from their corresponding influent. Although OTC use was associated with the increased occurrence and diversity of tet^R genes in water samples, it was not found to relate to tet^R gene occurrence in sediment samples. Sediment samples from facilities with no recent OTC use had significantly higher frequencies of tet^R gene detection than did samples from facilities with recent OTC use. All of the tet^R genes were detected in both the medicated and nonmedicated feed samples analyzed in this study. These findings suggest that both OTC treatment in aquaculture facilities and the farms themselves may be sources of tet^R gene introduction to the environment. To our knowledge, this is the first study to use genotypic and cultivation-independent methods to examine tet^R gene occurrence associated with OTC use in aquaculture.

Tello, A., Corner, R.A., and Telfer, T.C. **How do land-based salmonid farms affect stream ecology?** *Environmental Pollution* 158(5): 1147-1158, 2010.

Notes: Increasing research is highlighting the fact that streams provide crucial ecosystem services through the biogeochemical and ecological processes they sustain. Freshwater land-based salmonid farms commonly discharge their effluents into low

order, headwater streams, partly due to the fact that adequate freshwater resources for production are commonly found in undisturbed areas. We review the effects of salmonid farm effluents on different biological components of stream ecosystems. Relevant considerations related to the temporal and spatial scales of effluent discharge and ecological effects are discussed. These highlight the need to characterize the patterns of stressor discharge when assessing environmental impacts and designing ecological effects studies. The potential role of multiple stressors in disrupting ecosystem structure and function is discussed with an emphasis on aquaculture veterinary medicines. Further research on the effects of veterinary medicines using relevant exposure scenarios would significantly contribute to our understanding of their impact in relation to other effluent stressors.

Tsapakis, M., Dakanali, E., Stephanou, E.G., and Karakassis, I. **PAHs and n-alkanes in Mediterranean coastal marine sediments: aquaculture as a significant point source.** *Journal of Environmental Monitoring* 12(4): 958-963, 2010.

Notes: The occurrence of polycyclic aromatic and aliphatic hydrocarbons in fish feed, sediment trap material and marine sediments was examined at two fish farms in the eastern Mediterranean. The average (min-max) concentrations of polycyclic aromatic hydrocarbons (PAHs) in fish feed and particulate effluents were 316 (287-351) ng g⁻¹ DW and 487 (475-499) ng g⁻¹ DW, respectively. Lower PAH levels were determined in the underlying marine sediments. In the surface sediments under the farms (0 m distance from the edge of the cages) and in the immediate vicinity, the concentration levels of n-alkanes and PAHs were significantly higher than in the surrounding sediments in both sites. PAHs and n-alkanes individual component profiles of fish feed and sinking material were similar with the corresponding profiles of the sediment samples collected in the immediate vicinity around the cages. On a daily basis, the average PAH sedimentation fluxes under the cages was 24.4 µg m⁻² d⁻¹, which is considerably higher compared with the observed PAH sedimentary fluxes in the open eastern Mediterranean. Our results imply that fish farming is a significant source of these persistent organic pollutants (POPs) in the marine environment and therefore a likely change in the scale of production might introduce new sources of environmental risk. Further work is required in order to develop an appropriate monitoring system for the sustainable development of the aquaculture sector.

Tacon, A.G.J., Metian, M., Turchini, G.M., and DeSilva, S.S. **Responsible aquaculture and trophic level implications to global fish supply.** *Reviews in Fisheries Science* 18(1): 94-105, 2010.

Notes: Hunger and malnutrition remain among the most devastating problems facing the world's poor and needy, and continue to dominate the health and well-being of the world's poorest nations. Moreover, there are growing doubts as to the long-term sustainability of many existing food production systems, including capture fisheries and aquaculture, to meet the future increasing global demands. Of the different agricultural food production systems, aquaculture (the farming of aquatic animals and plants) is widely viewed as an important weapon in the global fight against malnutrition and poverty, particularly within developing countries where over 93% of global production is currently produced, providing in most instances an affordable and a much needed source of high quality animal protein, lipids, and other essential nutrients. The current article compares for the first time the development and growth of the aquaculture sector and capture fisheries by analyzing production by mean trophic level. Whereas marine capture fisheries have been feeding the world on high trophic level carnivorous fish species since mankind has been fishing the oceans, aquaculture production within developing countries has focused, by and large, on the production of lower trophic level species. However, like capture fisheries, aquaculture focus within economically developed countries has been essentially on the culture of high value-, high trophic level-carnivorous species. The long term sustainability of these production systems is questionable unless the industry can reduce its dependence upon capture fisheries for sourcing raw materials for feed formulation and seed inputs. In line with above, the article calls for the urgent need for all countries to adopt and adhere to the principles and guidelines for responsible aquaculture of the FAO Code of Conduct for Responsible Fisheries.

Péron, G., Mittaine, J.-F., and Le Gallic, B. **Where do fish meal and fish oil products come from? An analysis of the conversion ratios in the global fishmeal industry.** *Marine Policy* 34(4): 815-820, 2010.

Notes: As a result of the stagnation of commercial fishery landings, aquaculture activities are expected to increase over the next decades to match the growing demand for marine protein. Overall, it is expected that the aquaculture sector could reduce

some of the fishing pressure applied to wild stocks. However, this development is likely to be limited by the availability of key aquaculture inputs, specifically fishmeal and fish oil products (FMFOP). Aquaculture provided 60 % (fish meal) and 80 % (fish oil) of the world total consumption of these products in 2007. FMFOP are generally derived from small pelagic fish species, but can also be derived from other sources. Identifying the origin of FMFOP is crucial to understanding the effects of this new pressure on marine social-ecological systems. Two factors are of particular importance in the reduction sector transforming wild fish into fishmeal or fish oil: the two "conversion ratios" (i.e. the ratio between the quantity of wild fish harvested and the resulting quantity of FMFOP, and the ratio between the quantity of FMFOP and aquaculture production), and the type of raw material used by the reduction sector. Based on trade and production databases from FAO and the International Fishmeal and Fish oil Organisation (IFFO), this paper proposes an approach to identify the origin of FMFOP. It shows that whereas different countries use different pelagic resources to produce FMFOP, other countries use non-pelagic sources, and some countries use pelagic resources for human consumption.

Pike, I.H. and Jackson, A. **Fish oil: production and use now and in the future.** *Lipid Technology* 22(3): 59-61, 2010.

Notes: The global production of fish oil is around one million tonnes. This production is expected to be maintained. Rich in long-chain omega-3 fatty acids, especially EPA and DHA, it can supplement diets inadequate in these fatty acids such as those in many Western countries. Farmed fish, especially oily fish such as salmonids fed on fish oil provide an excellent source of these acids. Fish oil can be used directly in a purified form (nutraceuticals) in a wide range of foods. The daily recommended intake of EPA plus DHA of 0.25 to 0.50 g can then be met.

Gozlan, R.E., Britton, J.R., Cowx, I., and Copp, G.H. **Current knowledge on non-native freshwater fish introductions.** *Journal of Fish Biology* 76(4): 751-786, 2010.

Notes: This review provides a contemporary account of knowledge on aspects of introductions of non-native fish species and includes issues associated with introduction pathways, ecological and economic impacts, risk assessments, management options and impact of climate change. It offers guidance to reconcile the increasing demands of certain stakeholders to diversify their activities using non-native fishes with the long-term sustainability of native aquatic biodiversity. The rate at which non-native freshwater fishes have been introduced worldwide has doubled in the space of 30 years, with the principal motives being aquaculture (39%) and improvement of wild stocks (17%). Economic activity is the principal driver of human-mediated non-native fish introductions, including the globalization of fish culture, whereby the production of the African cichlid tilapia is seven times higher in Asia than in most areas of Africa, and Chile is responsible for c. 30% of the world's farmed salmon, all based on introduced species. Consequently, these economic benefits need balancing against the detrimental environmental, social and economic effects of introduced non-native fishes. There are several major ecological effects associated with non-native fish introductions, including predation, habitat degradation, increased competition for resources, hybridization and disease transmission. Consideration of these aspects in isolation, however, is rarely sufficient to adequately characterize the overall ecological effect of an introduced species. Regarding the management of introduced non-native fish, pre-introduction screening tools, such as the fish invasiveness scoring kit (FISK), can be used to ensure that species are not introduced, which may develop invasive populations. Following the introduction of non-native fish that do develop invasive populations, management responses are typified by either a remediation or a mitigation response, although these are often difficult and expensive to implement, and may have limited effectiveness.

Haupt, T.M., Griffiths, C.L., Robinson, T.B., and Tonin, A.F.G. **Oysters as vectors of marine aliens, with notes on four introduced species associated with oyster farming in South Africa.** *African Zoology* 45(1): 52-62, 2010.

Notes: Translocated oysters are well known to act as vectors of marine alien species, but to date this topic has received scant attention in South Africa, despite the fact that oysters have been imported into this region since 1894. Surveys of oyster farms in South Africa revealed four newly-recorded alien species: the black sea urchin, *Tetrapygus niger*, from Chile; the European flat oyster, *Ostrea edulis* (thought to be extinct since its intentional introduction in 1946); Montagu's crab, *Xantho incisus*, from the North Eastern Atlantic seas of Europe, and the brachiopod *Disciniscus tenuis* from Namibia. Oyster imports are the most likely

vector of all these species. The biological attributes of each species, the possible threats posed by their introduction, and the needs for additional control measures to limit or prevent further introduction and spread of alien species via oyster culture are discussed.

Grigorakis, K. Ethical issues in aquaculture production. *Journal of Agricultural and Environmental Ethics* 23(4): 345-370, 2010.

Notes: The ethical issues raised by aquaculture were analyzed. A modification of the Ethical Matrix of the Food Ethics Council for the evaluation of novel foods was used; the Ethical Matrix was changed in order to include the various aquaculture production stages separately. The following stages were distinguished: the breeding stage, the growth/feeding stage, the "other-handling" stage (that includes disease and treatment, transportation of organisms, killing procedure, and DNA vaccinations), and the commercialization stage. The ethical issues concerning the producers, the consumers, the environment, and the aquacultured organisms, are discussed. This scheme was fitted to the intensive cage-culture of carnivorous fish. The differences with other forms of aquaculture are discussed, and how the scheme extrapolates to them. The ethical evaluation of aquaculture, in practice, will be rather a utilitarian balancing of cost and benefits of the respective actions. The desired characteristics of an ethical evaluation have been also outlined. Ethical evaluation should not be limited to a purely scientific analysis; it should be holistic, comparable to available alternatives, and should have the flexibility to incorporate new data generated in the fast growing/continuous changing aquaculture sector.

Haws, M. et al. Aquaculture research and development as an entry-point and contributor to natural resources and coastal management. *Coastal Management* 38(3): 238-261, 2010.

Notes: Recent, fervent international dialogue concerning the existence and magnitude of impacts associated with aquaculture has had both positive and negative outcomes. Aquaculture stakeholders have become sensitized to requirements for improved environmental management of aquaculture. On the other hand, in some cases aquaculture development has been negatively affected by some of the unwarranted and unproved allegations to the detriment of the stakeholders most in need of aquaculture development (i.e., resource users, particularly the poor, who are dependent on natural resources). These resource users are targeted by, and directly influence biodiversity and conservation agendas; hence the need to understand how to gain their active participation. This discussion focuses on examples of how aquaculture research and development can be a useful tool or strategy for resource management initiatives and provide tangible positive including increased stakeholder participation and cooperation, offering alternatives to resource extraction and use in otherwise difficult or intransigent resource management conflicts.

Bush, S.R., van Zwieten, P.A.M., Visser, L., van Dijk, H., Bosma, R., de Boer, W.F., and Verdegem, M. Scenarios for resilient shrimp aquaculture in tropical coastal areas. *Ecology and Society* 15(2): art. 15, 2010. [O/A](#)

Notes: We contend there are currently two competing scenarios for the sustainable development of shrimp aquaculture in coastal areas of Southeast Asia. First, a landscape approach, where farming techniques for small-scale producers are integrated into intertidal areas in a way that the ecological functions of mangroves are maintained and shrimp farming diseases are controlled. Second, a closed system approach, where problems of disease and effluent are eliminated in closed recirculation ponds behind the intertidal zone controlled by industrial-scale producers. We use these scenarios as two ends of a spectrum of possible interactions at a range of scales between the ecological, social, and political dynamics that underlie the threat to the resilience of mangrove forested coastal ecosystems. We discuss how the analytical concepts of resilience, uncertainty, risk, and the organizing heuristic of scale can assist us to understand decision making over shrimp production, and in doing so, explore their use in the empirical research areas of coastal ecology, shrimp health management and epidemiology, livelihoods, and governance in response to the two scenarios. Our conclusion focuses on a series of questions that map out a new interdisciplinary research agenda for sustainable shrimp aquaculture in coastal areas.

Ahmed, N. and Troell, M. **Fishing for prawn larvae in Bangladesh: An important coastal livelihood causing negative effects on the environment.** *Ambio* 39(1): 20-29, 2010. O/A

Notes: Freshwater prawn (*Macrobrachium rosenbergi*) farming in Bangladesh has, to a large extent, been dependent on the supply of wild larvae. Although there are 81 freshwater prawn hatcheries in the country, a lack of technical knowledge, inadequate skilled manpower, and an insufficient supply of wild broods have limited hatchery production. Many thousands of coastal poor people, including women, are engaged in fishing for wild prawn larvae along the coastline during a few months each year. On average, 40% of the total yearly income for these people comes from prawn larvae fishing activity. However, indiscriminate fishing of wild larvae, with high levels of bycatch of juvenile fish and crustaceans, may impact negatively on production and biodiversity in coastal ecosystems. This concern has provoked the imposition of restrictions on larvae collection. The ban has, however, not been firmly enforced because of the limited availability of hatchery-raised larvae, the lack of an alternative livelihood for people involved in larvae fishing, and weak enforcement power. This article discusses the environmental and social consequences of prawn larvae fishing and concludes that, by increasing awareness among fry fishers, improving fishing techniques (reducing bycatch mortality), and improving the survival of fry in the market chain, a temporal ban may be a prudent measure when considering the potential negative impacts of bycatch. However, it also suggests that more research is needed to find out about the impact of larvae fishing on nontarget organisms and on the populations of targeted species.

Chávez-Crooker, P. and Obreque-Contreras, J. **Bioremediation of aquaculture wastes.** *Current Opinion in Biotechnology* 21(3): 313-317, 2010.

Notes: Environmental impacts of wastes from large-scale, intensive aquaculture are substantial and can lead to complex ecosystem changes. The application of known and new technologies can capture inorganic nitrogen from water and reduce organic enrichment of sediments. Biological methods, including Integrated Multi-trophic Aquaculture are now gaining interest for increasing *in situ* removal of nitrogen and other nutrients at sea cage sites. Several studies on biological nitrogen removal through nitrification, denitrification and anaerobic ammonium oxidation (anammox) have been reported and a number of bacterial groups active in this regard have been described. Nevertheless, additional efforts need to be focused on remediation of aquaculture wastewater and marine sediments. Conventional treatment systems have several disadvantages. Development of more efficient reactor systems and a holistic, integrated approach to waste treatment would allow more environmentally balanced aquaculture practices.

Citarasu, T. **Herbal biomedicines: a new opportunity for aquaculture industry.** *Aquaculture International* 18(3): 403-414, 2010.

Notes: Hormones, antibiotics, vitamins and several other chemicals have been tested in aquaculture operations for various remedies. Even though they give positive effects, they cannot be recommended due to their residual and other side effects. The alternative herbal bio-medicinal products in the aquacultural operations, that have the characteristics of growth promoting ability and tonic to improve the immune system, act as appetite stimulators. They increase consumption, induce maturation, and have antimicrobial capability and also antistress characteristics that will be of immense use in the culture of shrimps and other fin fishes without any environmental and hazardous problems. Herbal compounds such as phenolics, polyphenols, alkaloids, quinones, terpenoids, lectines and polypeptides have been shown to be very effective alternatives to antibiotics and other synthetic compounds. The present paper is presented after a careful review of more than 50 herbal plants for their biological effects such as growth promotion, immunostimulation, antistress, antibacterial, antifungal, antivirals, appetite stimulators and aphrodisiac

Saikku, L. and Asmala, E. **Eutrophication in the Baltic Sea : the role of salmonid aquaculture, consumption, and international trade.** *Journal of Industrial Ecology* 14(3): 482-495, 2010.

Notes: Fish consumption is increasing globally. Overfishing puts pressure on fisheries, but aquaculture provides an alternative to satisfy the growing need for seafood. However, nutrient emissions from aquaculture contribute to eutrophication, and

raising fish from the top of the food chain is inefficient. Here we use the approach of industrial ecology and report ImpACT decomposition analysis of the drivers of nutrient emissions to the Baltic Sea from rainbow trout aquaculture in Finland during 1980-2007. During this period, the nitrogen load studied increased markedly and was 522 tonnes in 2007. The phosphorus load quadrupled and then returned to its original level of about 65 tonnes. The Finnish population increased slightly, while the average affluence level increased significantly. Total salmonid consumption increased substantially during the period. The increasing percentage of imported salmonids and improvements in domestic aquaculture technology ended the period of strong growth of emissions in the 1980s. Decreasing the nutrient load through reductions in salmonid consumption in the future is unlikely, due to health benefits and consumer preferences. Replacing domestic production with import of salmonids raises questions regarding outsourcing of the environmental impact, and regarding rural development in Finland. Major improvements in production technology are not in sight. New perspectives on rainbow trout aquaculture may be needed, including using feed from the Baltic Sea, thus closing the nutrient cycle or changing consumption and production to herbivorous fish species.

Nayak, S.K. **Probiotics and immunity: A fish perspective.** *Fish and Shellfish Immunology* 29(1): 2-14, 2010.

Notes: Probiotics are usually live microorganisms which when administered in adequate amounts confer health benefits on the host. Nowadays, probiotics are also becoming an integral part of the aquaculture practices to obtain high production. The common probiotics that are used for aquaculture practices include **Lactobacillus, Lactococcus, Leuconostoc, Enterococcus, Carnobacterium, Shewanella, Bacillus, Aeromonas, Vibrio, Enterobacter, Pseudomonas, Clostridium, and Saccharomyces** species. The involvement of probiotics in nutrition, disease resistance and other beneficial activities in fish has been proven beyond any doubt. Among the numerous health benefits attributed to probiotics, modulation of immune system is one of the most commonly purported benefits of the probiotics and their potency to stimulate the systemic and local immunity under in vitro and in vivo conditions is noteworthy. Different probiotics either monospecies or multispecies supplementation can eventually elevate phagocytic, lysozyme, complement, respiratory burst activity as well as expression of various cytokines in fish. Similarly, probiotics can stimulate the gut immune system of fish with marked increase in the number of Ig+ cells and acidophilic granulocytes. Furthermore, mono-bacterial association studies (with non-probiotic bacterial strains) in gnotobiotic fish also indicate the up-regulation of various immune related genes. Though the exact mode of action of probiotics is yet to be established in any animal including fish, probiotics often exert host specific and strain specific differences in their activities. Various factors like source, type, dose and duration of supplementation of probiotics can significantly affect the immunomodulatory activity of probiotics. The review is, therefore, aiming to highlight the immunomodulatory activity of probiotics and also to evaluate the factors that regulate for the optimum induction of immune responses in fish.

Magnadottir, B. **Immunological control of fish diseases.** *Marine Biotechnology* 12(4): 361-379, 2010.

Notes: All metazoans possess innate immune defence system whereas parameters of the adaptive immune system make their first appearance in the gnathostomata, the jawed vertebrates. Fish are therefore the first animal phyla to possess both an innate and adaptive immune system making them very interesting as regards developmental studies of the immune system. The massive increase in aquaculture in recent decades has also put greater emphasis on studies of the fish immune system and defence against diseases commonly associated with intensive fish rearing. Some of the main components of the innate and adaptive immune system of fish are described. The innate parameters are at the forefront of immune defence in fish and are a crucial factor in disease resistance. The adaptive response of fish is commonly delayed but is essential for lasting immunity and a key factor in successful vaccination. Some of the inherent and external factors that can manipulate the immune system of fish are discussed, the main fish diseases are listed and the pathogenicity and host defence discussed. The main prophylactic measures are covered, including vaccination, probiotics and immunostimulation. A key element in the immunological control of fish diseases is the great variation in disease susceptibility and immune defence of different fish species, a reflection of the extended time the present day teleosts have been separated in evolution. Future research will probably make use of molecular and proteomic tools both to study important elements in immune defence and prophylactic measures and to assist with breeding programmes for disease resistance.

Middlemas, S.J., Raffell, J.A., Hay, D.W., Hatton-Ellis, M., and Armstrong, J.D. **Temporal and spatial patterns of sea lice levels on sea trout in western Scotland in relation to fish farm production cycles.** *Biology Letters* 6(4): 548-551, 2010.

Notes: The relationship between aquaculture and infestations of sea lice on wild sea trout (*Salmo trutta*) populations is controversial. Although some authors have concluded that there is a link between aquaculture and lice burdens on wild fish, others have questioned this interpretation. Lice levels have been shown to be generally higher on Atlantic salmon farms during the second years of two-year production cycles. Here we investigate whether this pattern relates to lice burdens on wild fish across broad temporal and spatial axes. Within Loch Shiel across five successive farm cycles from 2000 to 2009, the percentage of sea trout with lice, and those above a critical level, were significantly higher in the second year of a two-year production cycle. These patterns were mirrored in 2002-2003 across the Scottish west coast. The results suggest a link between Atlantic salmon farms and sea lice burdens on sea trout in the west of Scotland.

Krkošek, M. **Sea lice and salmon in Pacific Canada: ecology and policy.** *Frontiers in Ecology and the Environment* 8(4): 201-209, 2010.

Notes: The spread of sea lice (*Lepeophtheirus salmonis*) from salmon farms probably contributes to declines of some native Pacific salmon populations. Migration normally protects juvenile wild Pacific salmon from the marine ectoparasite in coastal waters by separating juvenile salmon from infected wild adults that are located offshore. Farmed salmon populations dwarf natural coastal host populations, particularly in winter, leading to biomagnification of louse populations. By spring, there may be large numbers of lice on farmed salmon, and this is associated with recurrent parasite infestations of wild juvenile salmon and depressed wild salmon stocks. Abiotic (eg temperature and salinity), biotic (eg predator abundance and food availability), and management (eg periodically emptying farms and applying chemical parasiticides) factors are thought to mediate the louse threat, but none have been well studied. Policy is needed that protects undeveloped juvenile salmon habitats and that supports long-term study of salmon ecosystems, to evaluate the sustainability of wild and farmed salmon.

Houde, A.L.S., Fraser, D.J., and Hutchings, J.A. **Fitness-related consequences of competitive interactions between farmed and wild Atlantic salmon at different proportional representations of wild-farmed hybrids.** *ICES Journal of Marine Science* 67(4): 657-667, 2010.

Notes: Escaped farmed fish possess heritable characteristics that may give them and their wild-farmed hybrid offspring a competitive advantage over wild fish. Limited research has examined whether the results of wild vs. farmed pairwise behavioural contests can predict the change in fitness-related traits of wild fish when exposed to wild-farmed hybrids, or to different proportions of such hybrids, within stream environments. Pairwise aggression tests on North American Atlantic salmon (*Salmo salar*) revealed that regional farmed salmon and wild-farmed hybrids (F₁, F₂, and wild backcrosses) were more competitive than wild fish from two divergent populations. The ranking by which hybrids differed in competitive ability from wild fish also depended on the wild population. However, the magnitude of change in fitness-related traits of wild fish, such as mortality, size, and condition, from the same two populations could not be predicted from pairwise test results when replicate groups of wild fish were exposed to different proportions of hybrids (wild:hybrid ratios of 50:50, 70:30, and 85:15) in semi-natural stream environments. Notably, there was greater mortality of both wild and hybrid fish in treatments containing 30% hybrids for both populations; at a composition of 50% hybrids, the mortality of wild fish in one population increased more than it did in the other. The results suggest that for the life stage examined and provided the rate of farmed intrusion and wild-farmed interbreeding remains low (i.e. ≤15% hybrids), the effects of competitive interaction with their farmed counterparts may have comparatively little effect on the mortality of wild populations.

Houde, A.L.S., Fraser, D.J., and Hutchings, J.A. **Reduced anti-predator responses in multi-generational hybrids of farmed and wild Atlantic salmon (*Salmo salar* L.).** *Conservation Genetics* 11(3): 785-794, 2010.

Notes: Cultured organisms undergo genetically-based behavioural changes that may reduce their ability to survive in the wild. This has raised concerns that interbreeding between escaped cultured and wild organisms will generate hybrids exhibiting maladaptive behaviours which may ultimately reduce the fitness of the wild counterpart. We compared anti-predator responses

in Atlantic salmon (*Salmo salar*) from two wild North American populations, the major farmed strain used in regional aquaculture, and their wild-farmed hybrids (F₁, F₂, and wild backcross). Anti-predator responses of fry (age 0+ parr) were measured under common environmental conditions, using a model of a natural predator (belted kingfisher, *Ceryle alcyon*). Farmed fry exhibited significantly reduced anti-predator responses relative to fry from both wild populations. The anti-predator responses of wild-farmed hybrid fry were intermediate to those of the parental populations (pure farmed or wild). The magnitude by which wild-farmed hybrids differed in anti-predator responses from pure wild fish also depended on the wild population. These results suggest that: (1) the observed behavioural differences have a genetic basis; (2) wild-farmed hybrids have, on average, reduced anti-predator responses relative to wild fish; and that (3) the effects of wild-farmed interbreeding on anti-predator responses will differ between wild populations. Our study is consistent with the general hypothesis that continual farmed-wild interbreeding may have detrimental effects on the fitness of wild organisms.

Bailey, M.M., Lachapelle, K.A., and Kinnison, M.T. **Ontogenetic selection on hatchery salmon in the wild: natural selection on artificial phenotypes.** *Evolutionary Applications* 3(4): 340-351, 2010. O/A

Notes: Captive rearing often alters the phenotypes of organisms that are destined for release into the wild. Natural selection on these unnatural phenotypes could have important consequences for the utility of captive rearing as a restoration approach. We show that normal hatchery practices significantly advance the development of endangered Atlantic salmon (*Salmo salar*) fry by 30+ days. As a result, hatchery fry might be expected to face strong natural selection resulting from their developmental asynchrony. We investigated patterns of ontogenetic selection acting on hatchery produced salmon fry by experimentally manipulating fry development stage at stocking. Contrary to simple predictions, we found evidence for strong stabilizing selection on the ontogeny of unfed hatchery fry, with weaker evidence for positive directional selection on the ontogeny of fed fry. These selection patterns suggest a seasonally independent tradeoff between abiotic or biotic selection favoring advanced development and physiological selection linked to risk of starvation in unfed fry. We show, through a heuristic exercise, how such selection on ontogeny may exacerbate problems in restoration efforts by impairing fry productivity and reducing effective population sizes by 13-81%.

Fraser, D.J., Houde, A.L.S., Debes, P.V., O'Reilly, P., Eddington, J.D., and Hutchings, J.A. **Consequences of farmed-wild hybridization across divergent wild populations and multiple traits in salmon.** *Ecological Applications* 20(4): 935-953, 2010.

Notes: Theory predicts that hybrid fitness should decrease as population divergence increases. This suggests that the effects of human-induced hybridization might be adequately predicted from the known divergence among parental populations. We tested this prediction by quantifying trait differentiation between multigenerational crosses of farmed Atlantic salmon (*Salmo salar*) and divergent wild populations from the Northwest Atlantic; the former escape repeatedly into the wild, while the latter are severely depleted. Under common environmental conditions and at the spatiotemporal scale considered (340 km, 12 000 years of divergence), substantial cross differentiation had a largely additive genetic basis at behavioral, life history, and morphological traits. Wild backcrossing did not completely restore hybrid trait distributions to presumably more optimal wild states. Consistent with theory, the degree to which hybrids deviated in absolute terms from their parental populations increased with increasing parental divergence (i.e., the collective environmental and life history differentiation, genetic divergence, and geographic distance between parents). Nevertheless, while these differences were predictable, their implications for risk assessment were not: wild populations that were equally divergent from farmed salmon in the total amount of divergence differed in the specific traits at which this divergence occurred. Combined with ecological data on the rate of farmed escapes and wild population trends, we thus suggest that the greatest utility of hybridization data for risk assessment may be through their incorporation into demographic modeling of the short- and long-term consequences to wild population persistence. In this regard, our work demonstrates that detailed hybridization data are essential to account for life-stage-specific changes in phenotype or fitness within divergent but interrelated groups of wild populations. The approach employed here will be relevant to risk assessments in a range of wild species where hybridization with domesticated relatives is a concern, especially where the conservation status of the wild species may preclude direct fitness comparisons in the wild.

Sundstrom, L.F., Lohmus, M., and Devlin, R.H. **Migration and growth potential of coho salmon smolts: implications for ecological impacts from growth-enhanced fish.** *Ecological Applications* 20(5): 1372-1383, 2010.

Notes: Wild-genotype and growth hormone (GH) transgenic coho salmon (with dramatically enhanced growth potential) were used to examine the influence of genotype, age, body size, growth, and rearing conditions on the onset of seaward migration and to assess the potential consequences of the introduction of such transgenic fish on natural ecosystems and wild populations. When reared from the first feeding stage under naturalized stream conditions, there was no difference in survival or migratory timing between the two genotypes. However, larger fish migrated earlier in the season than smaller fish of both genotypes, and transgenic fish with higher specific spring growth rates migrated earlier in the season than slower-growing transgenic fish. Stream-reared fish of both genotypes also displayed increased migratory activity at dawn and dusk. Fish reared in the hatchery for 3 and 15 months before being released into the stream in August differed in onset of seaward migration due mainly to age (older fish migrated earlier in the season) and genotype (transgenic fish migrated before wild-type in younger fish). Further, hatchery-reared fish showed no diel pattern in activity during migration. In older fish, larger individuals migrated later in the season than small individuals, whereas there was no clear size effect in younger individuals. Thus, although small differences in spring migration timing were observed among groups, seaward migration in coho salmon was largely independent of major shifts in size and growth rate induced by GH transgenesis (i.e., transgenic fish migrated at approximately the normal time in the spring, rather than at the typical size). Further, early rearing conditions had a stronger effect on migratory behavior than did the growth-promoting transgene. Taking into account effects of migratory timing, growth, survival, and differential food conversion efficiencies, these data suggest that transgenic fish escaped from hatcheries would have a greater impact on stream ecosystems during early life compared to escaped wild-type fish. However, this difference may be reduced if rearing occurred in subsequent generations under wild conditions where growth rates of transgenic fish are reduced compared with hatchery conditions.

Hardy, R.W. **Utilization of plant proteins in fish diets: effects of global demand and supplies of fishmeal.** *Aquaculture Research* 41(5): 770-776, 2010.

Notes: Aquafeed ingredients are global commodities used in livestock, poultry and companion animal feeds. Cost and availability are dictated less by demand from the aquafeed sector than by demand from other animal feed sectors and global production of grains and oilseeds. The exceptions are fishmeal and fish oil; use patterns have shifted over the past two decades resulting in nearly exclusive use of these products in aquafeeds. Supplies of fishmeal and oil are finite, making it necessary for the aquafeed sector to seek alternative ingredients from plant sources whose global production is sufficient to supply the needs of aquafeeds for the foreseeable future. Significant progress has been made over the past decade in reducing levels of fishmeal in commercial feeds for farmed fish. Despite these advances, the quantity of fishmeal used by the aquafeed sector has increased as aquaculture production has expanded. Thus, further reduction in percentages of fishmeal in aquafeeds will be necessary. For some species of farmed fish, continued reduction in fishmeal and fish oil levels is likely; complete replacement of fishmeal has been achieved in research studies. However, complete replacement of fishmeal in feeds for marine species is more difficult and will require further research efforts to attain.

Bureau, D.P. and Hua, K. **Towards effective nutritional management of waste outputs in aquaculture, with particular reference to salmonid aquaculture operations.** *Aquaculture Research* 41(5): 777-792, 2010.

Notes: Long-term sustainability of many fish culture operations may be dependent on their ability to reduce their waste outputs. The release of solid wastes is mainly a function of the digestibility of various dietary components, and the release of dissolved wastes is mainly a function of the metabolism of nutrients by the fish. Consequently, simple principles of nutrition and models have been effectively used to describe, predict and manage the excretion of wastes by fish. Nutritional strategies offer a direct and effective way of managing waste output by aquaculture operations. Very significant reduction in waste outputs per unit of fish produced, notably in terms for solid and phosphorus wastes, have been achieved over the past few decades by commercial fish culture operations. Further reduction in waste outputs could be achieved through fine-tuning of feed formulations, judicious use of feed additives and processing/refining of ingredients. A better understanding of the basis

of the effect of various endogenous (biological) and exogenous (dietary, environmental) factors on nutrient utilization by fish could also contribute to the development of strategies for reducing waste outputs. The present paper provides a brief overview of issues and challenges related to potential environmental impacts of wastes, and of recent progresses relative to nutritional strategies aimed at better management of the release of wastes by aquaculture operations.

Conceição, L.E.C., Yufera, M., Makridis, P., Morais, S., and Dinis, M.T. **Live feeds for early stages of fish rearing.** *Aquaculture Research* 41(5): 613-640, 2010.

Notes: Despite the recent progress in the production of inert diets for fish larvae, feeding of most species of interest for aquaculture still relies on live feeds during the early life stages. Independently of their nutritional value, live feeds are easily detected and captured, due to their swimming movements in the water column, and highly digestible, given their lower nutrient concentration (water content >80%). The present paper reviews the main types of live feeds used in aquaculture, their advantages and pitfalls, with a special emphasis on their nutritional value and the extent to which this can be manipulated. The most commonly used live feeds in aquaculture are rotifers (*Brachionus* sp.) and brine shrimp (*Artemia* sp.), due to the existence of standardized cost-effective protocols for their mass production. However, both rotifers and *Artemia* have nutritional deficiencies for marine species, particularly in essential n-3 highly unsaturated fatty acids (HUFA, e.g., docosahexaenoic acid and eicosapentaenoic acid). Enrichment of these live feeds with HUFA-rich lipid emulsions may lead to an excess dietary lipid and sub-optimal dietary protein content for fish larvae. In addition, rotifers and *Artemia* are likely to have sub-optimal dietary levels of some amino acids, vitamins and minerals, at least for some species. Several species of microalgae are also used in larviculture. These are used as feed for other live feeds, but mostly in the 'green water' technique in fish larval rearing, with putative beneficial effects on feeding behaviour, digestive function, nutritional value, water quality and microflora. Copepods and other natural zooplankton organisms have also been used as live feeds, normally with considerably better results in terms of larval survival rates, growth and quality, when compared with rotifers and *Artemia*. Nonetheless, technical difficulties in mass-producing these organisms are still a constraint to their routine use. Improvements in inert microdiets will likely lead to a progressive substitution of live feeds. However, complete substitution is probably years away for most species, at least for the first days of feeding.

Guimarães, A.S., Travassos, P., Souza, P.W.M.E.F., Gonçalves, F.D., and Costa, F. **Impact of aquaculture on mangrove areas in the northern Pernambuco Coast (Brazil) using remote sensing and geographic information system.** *Aquaculture Research* 41(6): 828-838, 2010.

Notes: The conversion of mangrove areas into shrimp farming ponds has been indicated as the main activity responsible for the reduction in the area of this ecosystem along the northeastern coast of Brazil. The present study was conducted using remote sensing methods and a geographical information system with the aim of quantifying the participation of this activity in the reduction of the mangrove areas along the northern coast of the State of Pernambuco (northeast, Brazil), where shrimp farming has been implanted in last recent years. From 1973 to 2005, there was reduction of about 2,052 ha of mangrove, 197 ha of which were converted into shrimp ponds. Thus, the real contribution of shrimp farming to this reduction was just 9.6% of the total area. Other anthropogenic activities, such as agriculture, urban expansion and tourism, contributed greatly to the reduction in the mangrove areas along the northern coast of the State of Pernambuco.

Alagarsamy, S., Thampuran, N., and Joseph, T.C. **Virulence genes, serobiotypes and antibiotic resistance profile of *Escherichia coli* strains isolated from aquaculture and other sources.** *Aquaculture Research* 41(7): 1003-1014, 2010.

Notes: In order to determine the prevalence of pathogenic *Escherichia coli*, a total number of 155 *E. coli* isolates from aquaculture, clinical and veterinary sources were screened for seven pathogenic virulence markers and a house-keeping gene by a polymerase chain reaction. The targeted virulence genes included *eaeA* of enteropathogenic *E. coli*, *elt* and *est* of enterotoxigenic *E. coli* (ETEC), *ipaH* of enteroinvasive *E. coli*, *pCVD432* of enteroaggregative *E. coli*, *stx*, *hlyA* and *eaeA* of shigatoxigenic *E. coli* (STEC) and enterohaemorrhagic *E. coli*. All the isolates were positive for *phoA*, the house-keeping gene for *E. coli*. Among the 155 isolates, seven numbers (4.5%) harboured the virulence markers belonging to the pathogenic group

ETEC and STEC. The virulent genes detected in these groups were **elt**, **est**, **hlyA** and **stx**. The sources of these virulence genes were fish (**hlyA**), shrimp (**elt**), feeder canal water (**hlyA** and **elt**) of aquaculture origin and from diarrhoea affected cow (**hlyA**, **est** and **stx**). The isolates with pathogenic traits belonged to the serogroups O6 or O29 and the remaining could not be typed. They showed resistance to two to four antibiotics out of the 12 antibiotics tested. Biotyping revealed that three isolates belonged to a single biotype (7333) and the remaining isolates were of diverse types. In conclusion, a molecular tool such as PCR proves as more effective tool for detection of this pathogen than the conventional methods. Detection of these emerging pathogens in aquaculture samples warrants for strict adherence to hygienic handling at retail outlets and proper cooking by the consumer before consumption.

Merrifield, D.L., Dimitroglou, A., Foey, A., Davies, S.J., Baker, R.T.M., Bogwald, J., Castex, M., and Ringo, E. **The current status and future focus of probiotic and prebiotic applications for salmonids.** *Aquaculture* 302(1-2): 1-18, 2010.

Notes: Salmonids are an important contributor to fish production in many countries. Concerted research efforts have concentrated on optimising production with eco-friendly alternatives to the therapeutic use of antimicrobials. Probiotics and prebiotics offer potential alternatives by providing benefits to the host primarily via the direct or indirect modulation of the gut microbiota. Suggested modes of action resulting from increased favourable bacteria (e.g. lactic acid bacteria and certain **Bacillus** spp.) in the gastrointestinal (GI) tract include the production of inhibitory compounds, competition with potential pathogens, inhibition of virulence gene expression, enhancing the immune response, improved gastric morphology and aiding digestive function. The application of probiotics and prebiotics may therefore result in elevated health status, improved disease resistance, growth performance, body composition, reduced malformations and improved gut morphology and microbial balance. Current research demonstrates successful proof of these concepts and a foundation for applications in salmonid aquaculture. However, application strategies applied in current studies are varied and often impractical at industrial level farming; thus, it is difficult to plan an effective feeding strategy for commercial level applications. Future studies should focus on providing practical industrial scale applications. Additionally, from a scientific perspective we must have a better understanding of the mucosal-bacterial interactions which mediate the host benefits in order to achieve optimal utilisation.

Koldewey, H.J. and Martin-Smith, K.M. **A global review of seahorse aquaculture.** *Aquaculture* 302(3-4): 131-152, 2010.

Notes: Seahorses (**Hippocampus** spp.) are flagship species for many issues in marine conservation including overexploitation, incidental bycatch and habitat loss. Aquaculture has been proposed as one solution to address unsustainable trade for traditional medicine, aquarium fishes and curios. Here we review historical and current information on global seahorse aquaculture including characteristics of aquaculture operations, species in culture, contribution to international trade and technical issues associated with raising seahorses in captivity. We found that prior to the 1990s, seahorse aquaculture was plagued by problems with disease and feeding. In the late 1990s and early 2000s there was considerable expansion in the number and size of aquaculture operations and the number of species in culture. This was reflected in an increasing contribution of captive-bred seahorses to the aquarium trade but not in the larger traditional medicine market. Currently, the majority of seahorse aquaculture involves small-scale operations in developed countries, employing relatively few personnel and selling live animals for the home aquarium market. Although, there are still considerable technical problems with diseases and with breeding and raising some species, others are performing successfully in aquaculture. There are currently at least 13 species in commercial culture or under research for their culture potential. However, economic viability remains a concern to many current aquaculture operations including price competition with wild-caught animals. Large-scale aquaculture to supply the traditional medicine market or as a livelihood venture has not yet been demonstrated to be commercially viable, although it is being actively researched.

Navarrete-Mier, F., Sanz-Lazaro, C., and Marin, A. **Does bivalve mollusc polyculture reduce marine fin fish farming environmental impact?** *Aquaculture* 306(1-4): 101-107, 2010.

Notes: The ability of bivalve culture in the proximity of an open water fin fish farm to reduce the environmental impact caused by organic wastes was tested. The experiment involved floating net cages containing cultured gilthead sea bream (**Sparus aurata**) and European sea bass (**Dicentrarchus labrax**) in the western Mediterranean. Two bivalve species, oyster (**Ostrea edulis**) and

mussel (*Mytilus galloprovincialis*), were deployed for 3 months along a distance transect running from 0 to 1800 m from the fish cages. Shell growth, flesh dry weight, the concentration of stable isotopes of carbon and nitrogen, and metal accumulation (Cd, Pb, Cu and Zn) in the bivalves were analyzed. Bivalves showed significant growth compared with their respective starting sizes, although closeness to the fish farm did not enhance such growth. The stable isotopes content indicated that there was no relationship between the main input of organic matter from the fish farm (the feed) and the trophic behavior of the bivalves. Neither did metal accumulation show a trend along the distance gradient from the fish farm. All the results were consistent in indicating that neither oysters nor mussels fed on fin fish farming wastes. This work demonstrates that the polyculture of fin fish and bivalves does not represent an appropriate tool for reducing the environmental impact of fin fish aquaculture in open water.

Nobre, A.M., Robertson-Andersson, D., Neori, A., and Sankar, K. **Ecological-economic assessment of aquaculture options: Comparison between abalone monoculture and integrated multi-trophic aquaculture of abalone and seaweeds.** *Aquaculture* 306(1-4): 116-126, 2010.

Notes: Integrated multi-trophic aquaculture (IMTA) possesses ecological and socio-economic advantages, relative to single-species aquaculture. The promotion of a sustainable aquaculture industry requires that decision-makers, ecosystem managers and farmers have sufficient quantitative information associated with its implementation from both public and private perspectives. The present paper applies the Differential Drivers Pressure State Impact Response (ADPSIR) methodological approach to an ecological and economic comparison between mono-aquaculture and IMTA. Data from a South African 240-ton year⁻¹ abalone farm were used as a case study. Three operation schemes were considered: abalone monoculture in a flow-through system; and two IMTA schemes, which recycle water and replace 10% and 30% of kelp consumption with on-farm-grown seaweed. The analysis indicates a decrease in the aquaculture generated ecological pressures with the incorporation of seaweeds, mainly a reduction in nitrogen discharges into the adjacent coastal ecosystem (by 3.7 to 5.0 tons year⁻¹), a reduction in harvest of natural kelp beds (by 2.2 to 6.6 ha year⁻¹) and a reduction of GHG emissions (by 290 to 350 tons CO_{2e} year⁻¹). Adopting an IMTA configuration raised farm profits by 1.4 to 5%. The corresponding overall gain from using IMTA in the case study is several folds larger than the net gain in profit, and is estimated between 1.1 and 3.0 million U.S. dollar per annum. This range of values reflects the gains of adopting IMTA on (i) economic value of the aquaculture, i.e. farm's profit, (ii) value of environmental externalities, and (iii) implementation costs. The analysis suggests that the value of the benefits to the public by adopting the IMTA configurations can be larger than the gains in farm's profitability.

Burridge, L., Weis, J.S., Cabello, F., Pizarro, J., and Bostick, K. **Chemical use in salmon aquaculture: A review of current practices and possible environmental effects.** *Aquaculture* 306(1-4): 7-23, 2010.

Notes: The World Wildlife Fund is facilitating a dialogue on impacts of salmon aquaculture. The goal of the dialogue is to establish the state of knowledge in seven subject areas associated with the industry: benthic impacts, nutrient loading, escapees, chemical inputs, diseases, feeds and social issues and to establish international standards for salmon aquaculture practices. Chemical inputs from salmon aquaculture include antifoulants, antibiotics, parasiticides, anaesthetics and disinfectants. The use and potential effects of these compounds are herein summarized for the four major salmon producing nations: Norway, Chile, UK and Canada. Regulations governing chemical use in each country are presented as are the quantities and types of compounds used. The problems associated with fish culture are similar in all jurisdictions, the magnitude of problems is not and the number of compounds available to the fish farmer varies from country to country. Unfortunately, the requirement to publically report chemical use is inconsistent among countries. Chemical use data are available from Norway, Scotland and parts of Canada. The government of Chile and some Canadian provinces, while requiring that farmers report disease occurrence, compounds prescribed and quantities used, do not make this information readily available to the public. The fact that these data are available from regulatory agencies in Scotland and Norway adds pressure for other jurisdictions to follow suit. Data such as these are essential to planning and conducting research in field situations.