ECOREGION General advice
SUBJECT OSPAR request on interactions between wild and captive fish stocks

Advice summary

ICES advises that finfish mariculture activities in the OSPAR area occur in coastal areas in open pens, and they are dominated by Atlantic salmon. Most interactions examined in this request are expected to be localized to the vicinity of the mariculture sites. However, although there is reasonable evidence that interactions occur, scientific support for the significance of identified interactions is generally weak. ICES advises that formal risk assessments prior to establishing new mariculture developments may help identify issues and prevent the development of negative interactions. Inclusion of genetic risks in such assessments is critical and is often over-looked. Collection of baseline data at an early stage of mariculture developments can better inform decision making.

The design and siting of mariculture cages to reduce escapes and the following of good husbandry practises are the most efficient means of minimizing negative interactions with marine mammals, wild stocks, and the local environment. Selective breeding and domestication of only a few species will further reduce the risk of hybridization and introgression from fish that do escape. Pathogen transmission and undesired genetic and ecological consequences of using antibiotics and other pharmaceuticals require additional mitigation measures. The mitigation of diseases and parasites in mariculture occurs at two scales: area-based (coordinated stocking, harvesting, and fallowing) and farm-based (vaccination, early pathogen detection, veterinary prescribed treatments, and depopulation or early harvest in the event of viral disease). Management zones, defined by local hydrography (using circulation models) and biological properties of infectious agents should be established for each farm or farm cluster.

Request

EIHA Requests for advice interactions between wild and captive fish stocks

a) *Recalling the conclusion of the QSR 2010 that mariculture is a growing activity in the OSPAR maritime area, EIHA 2012 considered the potential for increasing environmental pressure relating to the growth of this industry. As yet this is not an established work stream within EIHA, and Contracting Parties have requested that more information be brought forwards on this issue. This was reiterated by EIHA 2013.*
b) *Mariculture has a number of associated environmental pressures such as the introduction of non-indigenous species, which can have ecological and genetic impacts on marine environment and especially on wild fish stocks; in addition, pressures from mariculture might include:*
    I. *introduction of antibiotics and other pharmaceuticals;*
    II. *transfer of disease and parasite interactions;*
    III. *release of nutrients and organic matters;*
    IV. *introgression of foreign genes, from both hatchery-reared fish and genetically modified fish and invertebrates, in wild populations;*
    V. *effects on small cetaceans, such as the bottlenose dolphin, due to their interaction with aquaculture cages*
c) *EIHA proposes that OSPAR requests ICES to provide:*
    I. *an update on the available knowledge on these issues;*
    II. *concrete examples of management solutions to mitigate these pressures on the marine environment;*
    III. *advice on which pressures have sufficient documentation regarding their impacts to implement relevant monitoring and suggest a way forward to manage these pressures.*
d) *It may be appropriate to explore cooperation with other competent authorities working in this field, such as the European Food Safety Authority with respect to disease transfer or parasites, or the North Atlantic Salmon Conservation Organisation (NASCO), in particular with respect to existing cooperation between NASCO and ICES on issues pertaining to pressures from mariculture.*

ICES advice

ICES notes that global aquaculture production continues to increase, but that the increases in marine finfish mariculture in the OSPAR region appeared to have slowed down and may be levelling off. Approximately 90% of this production is from Atlantic salmon, with rainbow trout, cod, gilthead bream, sea bass, and turbot making up the remainder.

In this advice, following the title “interactions between wild and captive fish stocks”, ICES focuses only on issues relating to mariculture for finfish in coastal locations and on the six topics raised in the request. ICES notes that the list of issues extends beyond “interactions of wild and captive fish stocks” and that a number of other environmental issues concerning finfish mariculture are not listed. There are also issues that are more prominent in shellfish culture than in finfish culture (e.g. introduction of non-native species). ICES noted some ambiguity in item c) III of the request and interpreted this broadly as "should monitoring for this issue be established?" In answering that question, ICES estimated the importance of each individual issue. In ideal circumstances this would be best assessed, upon request, using a more formal risk assessment.

I. Introduction of antibiotics and other pharmaceuticals

i. update on knowledge

Numerous studies have documented resistance development in species of *Aeromonas* and of *Vibrio*, *Yersinia ruckerii*, and *Edwardsiella tarda* that affect fish. Environmental effects are less clear but oxytetracycline resistance has been detected in bacteria in sediments. The scale of effects on non-target organisms is unclear, but appears to be minor.

The use of pesticides for sea lice control, disinfectants, and anaesthetics in aquaculture has been studied extensively. In respect of pesticides, negative impacts on non-target organisms in the sea are considered minor. In recent years resistance in sea lice to baths of pyrethroids or hydrogen peroxide, and to emamectin benzoate included in feed, has led to flubenzurones (di- and teflubenzuron) and to cleaner fish (wrasse and lumpfish) being used increasingly.

Teflubenzuron residues have been found in crustaceans in the wild and in separate laboratory studies adverse effects were noted in juvenile European lobsters. The spatial scale and significance of these effects in the sea are not known. A study found that residues of emamectin benzoate in blue mussels 100 metres from treated fish cages were fully depurated within one month. Residues in the sediment 10 metres from the cages also depurated post treatment but at a slower rate, with residues detectible up to 12 months post treatment. Anaesthetic use was considered of little risk due to low volumes and infrequent usage.

ii. management solutions to mitigate pressures on the marine environment

Pruden *et al*. (2013) reviewed the management options to reduce the use of antibiotics (and therefore unwanted consequences) and their release into the environment. Four options were explored: the use of vaccines, increased bio-security, better feeding control to reduce waste feed, and the use of dried food pellets in place of wet diets. All options were found to be useful, although the effectiveness and appropriateness of each option depended upon the local circumstances. Banerjee *et al*. (2014) also addressed the issue of drug use in aquaculture through management and treatment of effluent linked with macrophyte-based remediation. The rapid detection and diagnosis of disease was identified as a key prerequisite to reduce antibiotic use. Alternatives to the use of therapeutants include the use of probiotics, essential oils, and phage therapy. Probiotics have been utilized with some success in teleost fish, in crustaceans, and in bivalves. Essential oils in feed have been used to reduce bacterial infection in trout. Phage therapy has also been used successfully in trout culture against *Aeromonas salmonicida*.

iii. monitoring needs

The amounts of antibiotics, pesticides, disinfectants, and anaesthetics could be monitored through notifications from trade or quantities prescribed for usage in fish farms. The scale at which any environmental effects of new chemicals used in mariculture occur should be monitored, as well as intermittent studies to determine if drug resistance is becoming more widespread. However, the pressure exerted by these chemicals in the OSPAR area appears to be low at present.

II. Transfer of disease and parasite interactions

i. update on knowledge

Open marine net pens facilitate virus and sea lice transfer, occasionally leading to infections and outbreaks of disease in farmed salmon. Epidemiological techniques and development of coastal circulation models permit the designation of areas of risk associated with sources of infection. Increased risk of exposure to neighbouring farms is inversely related to distance from and positively related to biomass at the source of infection. Susceptible wild or farmed fish occupying an area of risk may have an increased likelihood of exposure to pathogens, infection, and disease. There is evidence for elevated levels of sea lice on wild salmonids in several areas associated with salmon mariculture. Studies on the survival of salmon smolts treated prior to release with sea lice therapeutants compared with untreated smolts suggests that sea lice can increase mortality; however, links to mariculture are not conclusive. Risk of pathogen transmission from farmed to wild populations is estimated indirectly from epidemiological data. Further direct surveillance of wild populations is required.

ii. management solutions to mitigate pressures on the marine environment

Disease mitigation in mariculture occurs at two scales: area-based (coordinated stocking, harvesting, and fallowing) and farm-based (vaccination, early pathogen detection, veterinary prescribed treatments, and depopulation or early harvest in the event of viral disease). Implementation of mitigation measures results in virus disease outbreaks of shorter duration with lower mortality and therefore reduces the likelihood of pathogen transmission. In contrast, the mitigation of sea lice transmission is less likely to be effective in some areas due to increasing parasite resistance to therapeutants and to the absence of treatment when parasites occur below management thresholds.

In order to optimize mitigation, management zones, defined by local hydrography (using circulation models) and biological properties of infectious agents, should be established for each farm or farm cluster. Management zones should incorporate limits to local biomass as well as protocols for coordinated activities such as stocking, disease pathogen monitoring, harvesting, using single age-classes and sea lice treatments.

iii. monitoring needs

Pathogen surveillance of adjacent wild populations, when feasible, is needed to document marine reservoirs of infection and to validate mariculture management practices. There is evidence of transfer of sea lice and pathogens between farmed and wild stocks of fish and evidence of the impact of sea lice at a local scale. However, there is no evidence to allow extrapolation of this impact to the wider scale.

The Fish Disease Index (FDI) is a tool for assessing environmental effects and uses disease data from common dab, flounder, and Baltic cod (ICES, 2014d). ICES recommends that the FDI be adapted to assess pathogen or sea lice impacts. Such an adaptation would require the systematic collection of disease-relevant data from cultured and wild salmon. It is also important that data are archived in an accessible format; which requires the establishment of data-sharing protocols.

III. Release of nutrients and organic matter

i. update on knowledge

Finfish mariculture can increase the amount of nutrient and organic loading to the adjacent environment. The magnitude of the increase and the effects of changes depend on a number of factors, including local hydrographic conditions, cage structures, and farmed biomass. Of greatest concern are the accumulation of particulate organic matter on the seabed (with consequential benthic community effects), locally reduced oxygen levels (both in the water column and on the seabed), and changes in nutrients that may contribute to harmful algal blooms.

ii. management solutions to mitigate pressures on the marine environment

The design and siting of mariculture cages is important. A recent modelling study shows that the presence of fish cages restricts water flow in the surface layer, but enhances it in the bottom layer. Model results indicate that a cage/site-specific optimal drag coefficient and an optimal cage depth do exist and that these may be useful to mitigate impacts of fish wastes.
Responsible husbandry practices, such as optimal feeding and stocking, will also reduce nutrient inputs. Fallowing of sites reduces longer-term effects, particularly in areas where organic matter is liable to build up.

iii. monitoring needs

Routine monitoring of the seabed, benthos, and water column is currently undertaken in many areas as part of environmental regulation. This should continue and be introduced where it is not currently occurring. In order for this information to be of use, standard methods should be employed and the data made accessible.

IV. Introgression of foreign genes, from both hatchery-reared fish and genetically modified fish and invertebrates, in wild populations

i. update on knowledge

Genetic effects of escaped mariculture fish have been demonstrated as pervasive in several natural populations caused by hybridization (first generation crosses between wild and farm fish) and introgression (genetic mixing caused by hybrids and their offspring crossing with wild fish over multiple generations). Genetic changes in wild species may also be caused by selective pressure from parasites, pathogens, and chemicals, including pesticides, disinfectants, and anaesthetics.

Negative fitness effects of hybridization and introgression have been demonstrated in several species and populations, although natural selection is expected to act against propagation of maladapted traits. The relationships between a specific level of genetic introgression and changes in fitness of wild populations are difficult to predict.

Spatial variation in the genetic structure of fish populations results from processes such as colonization, genetic drift, and natural selection operating over many generations. The vast majority of fish produced in mariculture constitute selectively bred and domesticated strains. Interbreeding with farm escapees can therefore significantly alter the composition of local gene pools of wild fish. This genetic introgression can lead to an erosion of locally adapted gene complexes, and thus potentially to maladaptive changes in functional traits that govern the productivity and ultimately the survival of local populations.

Many wild stocks of salmonids are depleted. Smaller and genetically less diverse wild populations are expected to be more susceptible to introgression. Species exhibiting extensive population and life-history diversity are likely to be more resilient to potential negative impacts of farm escapees at an ecosystem level, due to decreased probability of survivorship of escapees and to strong selective pressures operating in the wild.

There is generally very limited information about genetic effects of the farm escapees on populations of non-salmonid marine fish species. As these species commonly have large populations with more exchange of migrants, it is expected that conducting a comprehensive assessment of the genetic impact of farm escapees will be even more challenging than in salmonids. Breeding processes have typically not been documented and may mask the frequency and direction of interactions.

There is some knowledge of the relationship between introgression and the long-term effects on fitness and survival in salmonids, but nothing is known for non-salmonids in the OSPAR region. Novel genomic analytical methods are expected to be useful for merging information about quantitative levels of genetic changes with qualitative assessment of effects on fitness in salmonids and other marine fish.

ii. management solutions to mitigate pressures on the marine environment

The most efficient way to minimize adverse genetic impacts is to avoid or reduce the escapement of fish into the wild. Escapes are usually the results of accidents, extreme weather or, more rarely, seals. The most appropriate solution is better management, the design of more robust cages, and ensuring maintenance of facilities. In addition, if mariculture focuses on a few highly domesticated fish species, wild stocks will be less affected by the escape of conspecifics.

The use of sterile farm fish has compelling strengths but major weaknesses have also been noted for some species and strains, especially those associated with impacts related to increased size. Genetic technologies that cause the death of fish that escape (gene blocking, gene knockout) are potential alternatives.

Environmental impact assessments of fish farms should include possibilities of genetic effects.

iii. monitoring needs

A recent risk assessment of Norwegian salmon farming concluded that genetic change resulting from interaction with escapees and salmon lice infections were the two most important farm-related threats to wild conspecifics. Genetic monitoring methods are already in place in some areas and for some species. Further development and application of genetic tools is needed to monitor the degree of introgression and to track origins of escapees. It is important that baseline samples are obtained both from ‘pure’ wild gene pools (prior to establishing farms in pristine areas) and from farmed fish.

V. *Effects on small cetaceans, such as the bottlenose dolphin, due to their interaction with aquaculture cages*

ICES is unaware of any major interactions between bottlenose dolphins and mariculture in the OSPAR area. ICES has therefore interpreted this question to apply to interactions with all marine mammals.

i. update on knowledge

The main interactions noted between marine mammals and mariculture are damage to gear and harm to fish, mammal entanglements in nets, ropes, and moorings, or disturbance to mammals.

Damage to gear and harm to fish

In the OSPAR area there are no records of cetaceans deliberately targeting farmed fish.

When foraging near fish farms, seals and other marine mammals tend to feed on wild fish aggregating outside the cages. In poorly designed facilities, seals sometimes prey on salmon through the cage netting. Seals can also breach weak containment netting, allowing fish to escape, occasionally in large numbers. In most countries, the number of fish escapements caused by marine mammals range from 2% to 5% of the events, although in Scotland in 2011 it was 27%.

Mammal entanglements in nets, ropes, and moorings

There is no systematic recording of entanglement in either fishing gear or fish farm installations for marine mammals in the OSPAR area. Entanglement of humpback whales has occurred in the UK and Norway. Some seal deaths may have been caused by such entanglement.

Disturbance to mammals

Acoustic deterrent devices (ADDs) are used in many places to reduce seal predation on farmed fish. Several studies have demonstrated that cetaceans (e.g. harbour porpoises and killer whales) can be excluded from areas in the immediate vicinity of farm sites where ADDs are being used. However, responses of cetaceans are variable. Harbour porpoises and other cetaceans have been recorded feeding approximately 200 m from active devices and returning to areas when the ADDs were switched off. All studies of these effects have been performed with the type of ADD that is most commonly used. Preliminary research with another ADD found that harbour porpoises showed weak or minimal responses to the sounds generated.

ii. management solutions to mitigate pressures on the marine environment

Many management measures are already in place, with the most effective being good cage design and maintenance along with good husbandry. ADDs and lethal shooting are used in areas of perceived conflict, although their use is either being phased out or is tightly regulated. Few data support the effectiveness of shooting and lethal control may not be necessary if the farm invests in other measures (e.g. seal-proof nets and/or better husbandry practices).

iii. monitoring needs

To assess the effects of ADDs on the overall distribution and behaviour of marine mammals, it will be necessary to gather information on the numbers and location of ADDs in use. The population level effects of lethal control of seals could be assessed through the use of reports of seals shot under licence.

VI. Introduction of non-indigenous species

i. update on knowledge

There have been few, if any, deliberate introductions of non-indigenous species in finfish mariculture in the OSPAR region. There have been escapes of non-indigenous species from finfish mariculture and introductions of such species have occurred in shellfish culture. Rainbow trout is the most notable non-indigenous fish species in mariculture in the OSPAR area. Escapes of this species have occurred, but there are no clear records in the OSPAR area of the species breeding or establishing a self-sustaining population following mariculture escapes.

ii. management solutions to mitigate pressures on the marine environment

The most efficient way to minimize escapes is to avoid or reduce the escapement of fish into the wild. Escapes are usually the results of accidents, extreme weather or, more rarely, seals. The most appropriate solution is better management, the design of more robust cages, and ensuring maintenance of facilities.

iii. monitoring needs

Notification of fish-farm escapes is required in most relevant jurisdictions in the OSPAR area. The collection and monitoring of these notifications would be a way of tracking the pressure of including additional “native” fish to the local environment. However, the pressure exerted on the OSPAR area appears to be low at present.

Sources

Banerjee, S., Kumar, V., and Pathak, A. N. 2014. Drug effects on aquaculture and its remediation. Journal of Drug Delivery and Therapeutics, 4: 117–122.

Burridge, L., Weis, J. S., Cabello, F., Pizarro, J., and Bostick, K. 2010. Chemical use in salmon aquaculture: a review of current practices and possible environmental effects. Aquaculture, 306: 7–23.

ICES. 2014a. Report of the Working Group on Marine Mammal Ecology (WGMME), 10–13 March 2014, Woods Hole, Massachusetts, USA. ICES CM 2014/ACOM:27. 228 pp.

ICES. 2014b. Report of the Working Group on the Application of Genetics in Fisheries and Mariculture (WGAGFM), 7–9 May 2014, Faro, Portugal. ICES CM 2014/SSGHIE:13.

ICES. 2014c. Second Interim Report of the Working Group on Aquaculture (WGAQUA), 31 March–4 April 2014, Vigo, Spain. ICES CM 2014/SSGHIE:04. 94 pp.

ICES. 2014d. Second Interim Report of the Working Group on Pathology and Diseases of Marine Organisms (WGPDMO), 25–28 February 2014, ICES Headquarters, Copenhagen, Denmark. ICES CM 2014/SSGHIE:02. 26 pp.

Pruden, A., Joakim Larsson, D. G., Amezquita, A., Collignon, P., Brandt, K. K., Graham, D. W., *et al*. 2013. Management options for reducing the release of antibiotics and antibiotic resistance genes to the environment. Environmental Health Perspectives, 121: 878–885.

Romero, J., Feijoo, C. G., and Navarrete, P. 2012. Antibiotics in aquaculture – use, abuse and alternatives. *In* Health and Environment in Aquaculture. E. Carvalho (ed.) InTech. 41 pp. Available from: http://www.intechopen.com/books/health-and-environment-in-aquaculture/antibiotics-in-aquaculture-use-abuse-and-alternatives.