Fish Escapes from Cage Aquaculture in the Mediterranean

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Escapes of juveniles and adults from sea cages have been reported for almost all species presently cultured around the world in this culture system and are caused by technical and operational failures, extreme sea conditions or predator activity. Recently fertilized eggs spawned by farmed individuals are also considered as a potential vector for introduction of farmed fish into marine ecosystems. This aspect has forced a redefinition of the term 'escapes from aquaculture' to include the escapement of fertilized eggs (Jørstad *et al*. 2008). The impact of escapes on wild populations or natural habitats has been comprehensively studied for species such as the Atlantic salmon, identifying frequently negative effects on wild salmon.

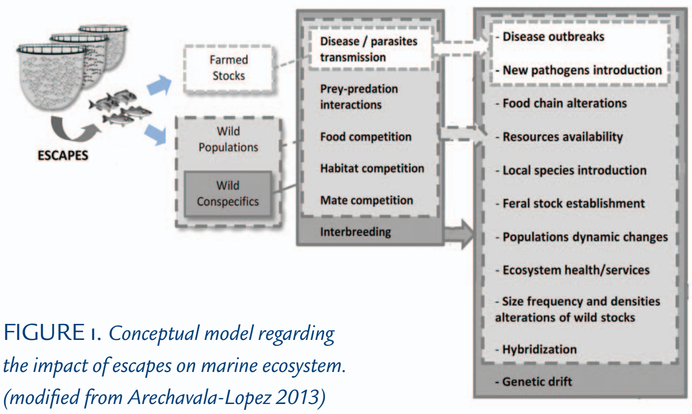


FIGURE 1. *Conceptual model regarding the impact of escapes on marine ecosystem. (modified from Arechavala-Lopez 2013)*

A recent study within the European project "Prevent-Escape" (Jackson *et al*. 2013; www.preventescape.eu) reported the causes of escaped fish based on questionnaires of producers in six European countries (Ireland, Scotland, Norway, Spain, Greece and Malta). In the Mediterranean, the main causes of escape incidents for seabream and seabass were caused by biological (51.5 percent; e.g. net biting, predator attack) or structural failures (39.4 percent; e.g. cage break, mooring failure, mechanical net damage), rather than operational failures (6 percent; e.g. harvesting, grading, transport).

Although there are no official statistics on the extent of escapes from cages in Mediterranean countries, data available from companies that insure fish farm businesses indicate that escapes were a significant component of economic losses claimed by farmers (EU FP-6 ECASA project; www.ecasa.org.uk). From 2001-2005, 76 claims accounting for 36 percent of the total value of all insurance claims made by fish farmers in Greece were related to stock losses from storms, while damage to farm equipment from storms accounted for 19 percent. Further, 39 registered 'predator attacks' resulted in claims of 10.4 percent of the total value of all insurance claims, although the proportion of this that relates to stock loss or cage damage is unknown. The existing evidence suggests that escapes were a relatively frequent occurrence on a pan-European scale, but impact intensity depended on environmental and genetic factors (Thorstad *et al*. 2008).

An Overview of Marine Finfish Aquaculture in the Coastal Mediterranean

The long shoreline and the oceanographic and geographic features of the Mediterranean Sea offer numerous possibilities for development of open-sea aquaculture and floating fish farms, comprised of tens of individual cages, widely used because of their adaptability to different sea conditions. Trujillo *et al*. (2011) analyzed the expansion of fish farms in the Mediterranean Sea, examining 91 percent of the Mediterranean coast, and counted 248 tuna cages (40-m diameter circular cages) and 20,976 other fish cages within 10 km of shore, the majority of which were off Greece (49 percent) and Turkey (31 percent). They estimated 225,736 t of farmed finfish (not including tuna) were produced in the Mediterranean Sea in 2006.

Considering only the Mediterranean and Black Sea Statistical Area (FAO Major Fishing Area 37), the aquaculture sector has developed rapidly and production has increased by over 42 percent over the last five years, from 291,838 t in 2004 to 415,036 t in 2008. Over the same period, production increased by 47.5 percent for Mediterranean countries in FAO Statistical Area 01 (North Africa).

The main growth in production in the Mediterranean Sea over the last 20 years is associated with marine finfish aquaculture, which has increased from 127,025 t in 1998 to 434,095 t in 2008, for an average annual growth rate of 16 percent. Most Mediterranean countries produce seabream *Sparus aurata* and seabass *Dicentrarchus labrax*, often coexisting in the same facility. The meagre *Argyrosomus regius* is becoming more widespread in the region, also sharing the same facilities.

Total seabream production in 2011 was 151,346 t (FEAP), compared to 155,805 t in previous years, indicating a slight decrease. Nineteen countries produce seabream; Greece is responsible for 60,000 t (39.6 percent), followed by Turkey (22.5 percent) and Spain (11.2 percent). Italy, Egypt, France, Cyprus, Portugal, Croatia, Malta, Albania, Libya and Tunisia also produce seabream. Other countries located outside of the natural distributional range of seabream have an incipient industry, such as the Dominican Republic, Unit Arab Emirates, Oman and

Kuwait (APROMAR 2011).

World production of seabass in 2011 was 126,240 t, a reduction of 5.8 percent from 2010. Main producers are Turkey with 43,200 t (34.2 percent), Greece (34.1 percent) and Spain (11.4 percent). This species is produced in nineteen countries, including Italy, France, Croatia, Portugal, Cyprus, Tunisia, Egypt, Unit Arab Emirates, Libya, Israel, Malta, Montenegro, Bosnia, Morocco, Slovenia, United Kingdom and Algeria.

In addition, Egypt produces more than 200,000 t per year of mullet, mainly *Mugil cephalus* in land-based facilities. As an emerging species, meagre production in Europe was 3,770 t in 2011, 4.2 percent less compared to 2010. Main producers of meagre are Spain (76.4 percent), France and Italy (APROMAR 2011).

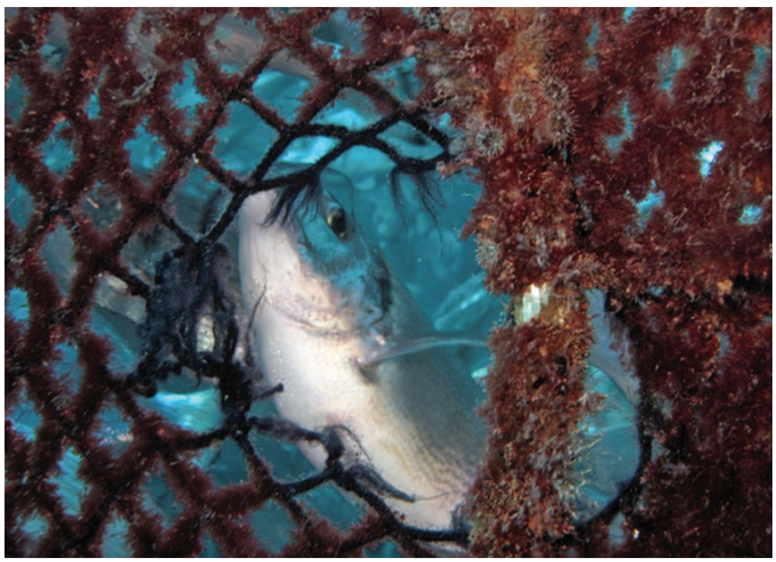
Potential Impacts of Seabream and Seabass Escapes

Despite the potential magnitude of impacts of escapes from Mediterranean fish farming, specific knowledge concerning ecological and genetic impacts of escaped fish on the Mediterranean ecosystem remains sparse. It is impossible to evaluate the evolving historical changes on wild fish populations specifically caused by escaped fish. For new species such as meagre the information is non-existent. However, drawing on experiences with Atlantic salmon, it is appropriate to assess the potential risk of escapes from cage aquaculture for improved environmental management and develop mitigating and contingent actions.

Other than genetic effects, the environmental effects of escaped fish on wild populations may be divided into five general categories:

- Exploitation competition: the possibility that escaped seabass and seabream affect wild conspecifics or other marine species indirectly through consumption (predation) of shared trophic resources.
- Interference competition: escaped seabass and seabream may compete directly with conspecifics or other species and interfere with foraging, survival and reproduction by preventing their physical establishment in natural habitats.
- Predation impact: escaped seabass and seabream affect wild conspecifics or other marine species directly through predation on them.
- Competition over mating opportunities may exist when wild seabass and seabream are out-competed by escaped fish or the occurrence of escaped fish disrupts the natural spawning pattern of wild fish.
- Escaped fish could spread diseases to conspecifics or other species.

Based on the available information regarding these impacts, the environmental risk assessment of seabass and seabream escapes can be characterized as having low intensity, low probability and high uncertainty.



TOP, FIGURE 2A. *Net holding seabream in a typical Mediterranean floating cage, with wild fish swimming around (Photo: P. Sanchez-Jerez).* BOTTOM, FIGURE 2B. *Holes favor the small scale escapes but also can produce bigger escapes if it is broken during a storm (Photo: P. Sanchez-Jerez).*

Regarding the transfer of disease, there is no clear evidence of pathogen transmission, except for some examples. Diamant (2007) described bacterial infection by *Mycobacterium marinum* and *Streptococus iniae*, typical of cultured stocks, causing morbidity and mortality in wild fish, indicating that intensive sea cage farming acted as pathogen "amplifiers," with diseases transmitted in both directions between wild and cultured fish populations, with the specificity (or lack of it) of each pathogen for a host playing an essential role.

Predation on conspecifics or other fish species is more probable for seabass. Young seabass form schools, but adults appear to be less gregarious; seabass feed chiefly on shrimps and molluscs, also on fishes. Juveniles feed on invertebrates, taking increasingly more fish with age and adults are obligate piscivores,

(CONTINUED ON PAGE 32)

(trophic level of 3.79).

Seabream are found in seagrass beds, sandy bottoms and the surf zone, commonly to depths of about 30 m, but adults may occur to 150 m depth. Seabream are sedentary, either solitary or in small aggregations. Seabream are mainly carnivorous, accessorily herbivorous, feeding on shellfish, including mussels and oysters (trophic level of 3.26). Competition for trophic resources on seagrass meadows will depend on the carrying capacity of natural ecosystems. This situation may arise after a large escape event in an area where wild populations are near the ecosystem carrying capacity.

FIGURE 3. *Typical array of cages in a Mediterranean fish farm of seabream and seabass (Photo: P. Sanchez-Jerez).*

Genetic Impacts of Escaped Fish

Most studies on the genetic impact of escapes have focused on Atlantic salmon. There is an overall lack of knowledge regarding genetic effects of seabass and seabream escapees on wild populations. Escapes have occurred since the 1990s, without evidence of deleterious effects on wild populations, at least at present. Fisheries professionals have not raised an alarm over the situation with seabass and seabream catch, inasmuch as escapes are producing a low intensity risk. However the lack of evidence could also be an indication of uncertainty and not the absence of effects. The research effort carried out during the last year has reduced the level of uncertainty to medium.

The typology of marine fish reproduction minimizes the genetic impacts derived from escapes because most species have exceptionally high dispersal and migratory capabilities, wide geographic distributional range and very high fecundities with pelagic dispersion. Nonetheless, striking differences in genetic structure have been found in certain cases (CIESM 2007). It is reasonable to expect that wild populations of species such as seabass and seabream will be less sensitive to eventual genetic swamping from the escape of caged fish. This assertion is based on the large population sizes and high dispersal capabilities through the larval stage of seabass and seabream.

Genes providing "good" or "bad" fitness are constantly been brought about by long range gene flow, especially in marine species, added or removed locally by strong selection pressures. At present, broodstock are derived primarily from wild populations. The apparent lack of geographically linked genetic structuring within the species decreases the risk for adverse genetic interactions from escaped fish or intentional population displacements (ICES WGEIM 2006).

However, selective breeding is one of the key priorities of seabream aquaculture for the European Union and some other countries have selective and domestication breeding programs. This can affect the genetic structure and increase risk for future interbreeding with wild populations. Also, the common practice for farmers to use breeders from different geographic origin could effect changes in allele frequencies and/or the introduction of non-native alleles into local populations in case of escapes from culture facilities, in particular from floating cages, or restocking programs (Sola *et al*. 2007).

Future concerns may occur if differences between wild and farmed populations are large. Landings of seabream from fisheries at Mediterranean and Atlantic ports is relatively constant year to year, with between 7,000 to 8,500 t (FAO, www.globefish.org). Aquaculture production is 94.4 percent of total seabream production, with 139,925 t in 2010. Seabass have a similar pattern, with a world culture production of 118,931 t (FEAP 2010). The seabass fishery landed 8,000 to 12,000 t per year, only 10 percent of the annual production. Consequently wild populations of seabass and seabream could be much smaller compared to farmed populations, especially in areas where farms are concentrated, with production up to 4,000 t per year in relatively small areas. Escape rate and receiving population size are critical questions for defining environmental impact of escapes. The magnitude of the environmental impact can increase progressively over time as wild populations become more important than wild populations of seabass and seabream.

Future Scenarios for New Species: Meagre and Rabbitfish as Case Studies

New economic resources are being provided by the European Union for diversification of species and products in European aquaculture. There is a research effort to develop new species to culture because finfish aquaculture in Europe is largely dominated by a few species. Therefore, in the future, potential for growth might also depend on the capacity of the sector for sustainable exploitation of aquatic biodiversity through species diversification.

Species selection for aquaculture development often poses an enormous challenge for decision-makers. Often, species selection considers criteria such as aquaculture potential (availability of juveniles or breeders from the wild), adaptation to local environmental conditions, rearing potential, growth rate, consumer acceptance and flesh quality (Quéméner *et al*. 2002), without considering the potential negative impact of escapes on ecosystem services.

The lack of information about how emerging species behave after an escape may pose future problems with escaped individuals, especially if escaped fish represent a species characterized by a high trophic level, large maximum size and a voracious appetite.

TOP LEFT, FIGURE 4A. *Escaped meagre captured by artisanal fisheries (Photo: P. Sanchez-Jerez).* TOP RIGHT, FIGURE 4B. *Old picture, around 50's, of a big meagre fished in Alicante.* BOTTOM LEFT, FIGURE 4C. *Escaped meagre captured by artisanal fisheries (Photo: David Izquierdo).* BOTTOM RIGHT, FIGURE 4D. *Escaped meagre captured by artisanal fisheries (Photo: David Izquierdo).*

This is the case with the meagre, which can reach 200 cm in total length (Quero and Vayne 1987) and a weight of more than 50 kg in the wild. It is euryhaline, can adapt to very diverse environments, has a fast growth rate and desirable flesh quality. The aquaculture potential of meagre in the Mediterranean is increasing, but this development is being carried out without regional assessments to evaluate the risk of escapes and determine mitigation and contingent strategies when escapes occur.

In southeast Spain, meagre is becoming relatively common in the catches of local fisherman (Sanchez-Jerez *et al*. 2011), following the local aquaculture development of the species, and its increase in catches as a result of escapes is quite obvious. Meagre is considered a Mediterranean species but, despite claims that the species existed previously in the area, there are no reports of its appearance in catches during the last 100 years and it had been considered extinct in almost every part of the region (Mayol *et al*. 2000). Therefore, meagre should be considered a new species for many regions of the Mediterranean and escapes may have deleterious effects, given its high predation activity and growth. It should be considered a new introduced species in certain other coastal ecosystems. Proper management of the meagre is essential for an optimal status of Mediterranean coastal ecosystems; escapes of meagre have potential consequences for local ecosystems and fisheries that should be evaluated before the implementation of commercial aquaculture at full scale.

In the long term, species with a low trophic level are also becoming increasingly important. In general, aquaculture is trying to decrease its reliance on fishmeal and fish oil in aquafeeds. The long-term sustainability of marine aquaculture depends on being able to grow marine herbivorous species. The vast majority of

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global finfish production is carried out with the use of aquafeeds with very little or no fishmeal because of the low trophic level of freshwater species such as carp, catfish and tilapia. Some effort has been made to improve knowledge on basic physiological functions and feed technology on species diversification in this way.

As an example, rabbitfish (*Siganus* spp.) are extensively produced in tropical countries such as Tanzania, Indonesia and Australia (Soto 2009). In the Mediterranean, aquaculture of *Siganus rivulatus* has started to develop. This species can be an alternative to high trophic level species such as seabream and seabass, reducing the environmental costs and dependence on small pelagic fish products for feeding. Research has been done on basic culture requirements, dietary needs and health (Saoud and Anastasiades 2012).

FIGURE 5. *Tagged seabream ready for release during an experiment about escapes recapture.*

However, rabbitfish is a non-native, introduced species. The genus *Siganus* is widely distributed in the Indo-West Pacific Region but *Siganus rivulatus* migrated to the eastern Mediterranean through the Suez Canal and has since established large populations in its new environment. The species has spread from Egypt to Libya and Greece and has also been recorded around Malta. Voluntary and or accidental introduction of exotic aquatic species (alien species) can negatively impact native ecosystems. The ICES Code of Practices on the Introductions and Transfers of Marine Organisms (2005) and the considerations and suggestions of the report on Alien Species in Aquaculture by IUCN (2006) should be considered before developing aquaculture of any non-native species.

If rabbitfish aquaculture is developed in the open ocean using cages, the most suitable system for a low-price species, escapes may have deleterious effects on natural habitats. For example, escapes of tens of thousands of rabbitfish can increase the herbivorous pressure on algae beds or affect fragile habitats, such as meadows of the seagrass *Posidonia oceanica*, which is also an important part of its diet.

Recommendations

Environmental risk, understood as the exposure to circumstances that cause potential ecosystem damage arising from an event, such as fish escapes, that is not managed appropriately, must be evaluated before making an investment. It is important to develop mitigating strategies and contingent actions because risk management needs to address both sides of the risk: what lies behind it (the source) and what lies in front of it (the consequences) (Husdal 2009). Risk impacts are addressed by using mitigating strategies aimed at eliminating the source or driver. Improved physical containment at marine fish farming sites, through research and development of fish-farming technology, has been a central recommendation of many international workshops and forums on the environmental impacts of escapees. For example, the FP-6 EU Coordinating Action on the genetic impact of aquaculture activities on native populations (GENIMPACT) has concluded that efforts should be made to prevent escapes. "Instead of trying to protect wild populations from escapees, the best logical solution would be to try to prevent escapes. This will rely on technical improvements from the industry …" (Triantafyllidis 2007). Therefore, for well-established species, the most important management issue at present is the need to reduce the numbers of escaped fish.

Contingent strategies are aimed at eliminating impacts, such as programs to recapture escapes. Recapture may be a practical option for reducing the impact of escape events. This is included in several regulations regarding the environmental management of escapes (Washington, WAC 220-76-120**;** Chile *RAMA 2001,* Article. 5 and 6; Canada, ZZA fishing licence) but have many practical difficulties. In addition to specific recapture measures, professional and recreational fisheries often record high recapture rates after escape events. A major proportion of escaped fish can be recaptured if the catch effort in an area within several kilometres of the farm is implemented early after the escape event and lasts for several weeks to minimize the survival of escaped fish.

Most critical would be the use of introduced species in marine aquaculture. The Berne Convention in 1979 provides that "each contracting party undertakes … to strictly control the introduction of non-native species," which is very difficult with floating cages. The EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora requires member states to "ensure that the deliberate introduction into the wild of any species which is not native to their territory is regulated so as not to prejudice natural habitats within their natural range or the wild native fauna and flora and, if they consider necessary, prohibit such introduction" (article 22(b)). More specifically, EU directives legislate to protect the ecosystem against adverse effects of aquaculture-related introduced organisms (Directive on the deliberate release into the environment of Genetically Modified Organisms; 90/220/

EEC) and Environmental Impact Assessment Directive and its amendment (85/337/EEC and 97/11/EC; Streftaris *et al*. 2005).

EU regulations define a procedure for the establishment at the national level of a system of permits for all new species introduced for aquaculture. Under the proposed measures, all projects intending to introduce a non-native species into an area for aquaculture must be submitted for approval to a national advisory committee. An environmental risk assessment (ERA) would be required. Only projects that are judged to be low risk would be granted a permit. If the risk was considered to be medium or high, the advisory committee would enter into dialogue with the applicant to see whether adequate mitigation procedures or technologies to reduce risk to an adequately low level were available (ICES 2006).

Escapes from conventional aquaculture have been controversial and several ethical issues have become evident. The introduction and escape of non-native species cause largely unknown effects on the natural environment and wild fish stocks and/or fisheries. The social acceptability and sustainability of Mediterranean aquaculture is closely interlinked with the reduction of escapes and associated environmental impacts.

Notes

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