

ECOLOGICAL IMPACTS OF SEAFARMING AND SEARANCHING¹

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ABSTRACT

Seafarming has ecological effects such as pollution and eutrophication of adjacent areas by excess food or by feces or modification of habitats by physical structures. More subtle effects on the communities result from heavy consumption of plankton or benthos by caged or enclosed farmed organisms and consequent reduction of availability of food to adjacent natural communities. Seapens, in which monocultures are reared, develop a radically different benthos from that in adjacent areas. Seafarms can become focal points from which pathogens and parasites can be spread.

Searanching, in which stocks are enhanced by the addition of hatchery-reared recruits, has the potential to cause significant changes in the composition and stability of marine communities. Enhanced recruitment of a species will have negative effects on both its prey and its competitors but will enhance the biomass of its predators.

Enhanced recruitment of a stock of apex predators will decrease the biomass of its prey and cause changes in the composition of the community. The effects of searanching are amenable to modelling, and the likely effects of proposed searanching schemes should be examined before these are implemented.

The magnitude of the effects of searanching will depend on the degree to which the area is naturally saturated with recruits of that species and on the rate of exploitation. Poor management of the stock, resulting in under- or over-exploitation, will have highly destabilizing effects on the communities.

Seafarming or searanching can have negative effects on the gene pools of natural stocks and result in changes in life histories or in behavior.

INTRODUCTION

The emergence of sophisticated technologies for cultivation of marine organisms, both in biological terms and in terms of the hardware available, is leading to a rapid expansion of interest in seafarming and searanching on a global basis.

Seafarming is a process whereby motile organisms are retained in enclosures or cages or, in the case of sessile organisms, cultivated on defined sectors of the seabed or on special structures created for their husbandry. Cultivation of brackishwater or marine organisms in seawater ponds or impoundments is excluded by this definition.

Searanching is a process whereby hatchery-reared stocks are introduced to marine areas, where they mingle with wild stocks of their congeners, are exposed to predators, and are, in due course, harvested by conventional fishing methods.

Such definitions become blurred in a restricted habitat or where the mobility of the organisms is limited or where predators are actively controlled. For example, shallow water species of fishes stocked into a small atoll lagoon would be bounded by oceanic depths. If predators were controlled or excluded and supplementary food provided, it would be difficult to decide whether the operation was searanching or seafarming.

The ecological effects of seafarming and searanching have received the greatest attention in relation to Atlantic salmon (*Salmo salar*), Japanese pearl oysters (*Pinctada fucata martensii*), and yellowtail (*Seriola quinqueradiata*). As seafarming and searanching expand in tropical developing countries, it is important that the possible effects, both negative and positive, on the environment and on associated biotic communities be recognized.

ECOLOGICAL EFFECTS OF SEAFARMING

The most common ecological effect of seafarming is the pollution or eutrophication of adjacent habitats by excess food or feces. The effects will be strongly mitigated by good water exchange.

In Norwegian fjords, only 10% of the sediment layer derived from salmon cages decomposes each year and the sediment layer and oxygen demand, therefore, increases for "several tens of years" before stability is reached (Aure and Stigebrandt 1990). Eutrophication effects are slight in shallow, well-flushed waters and are restricted to an increase in phytoplankton in summer months and consequent decrease in water clarity. Deep basins with poor water exchange will be adversely affected by deoxygenation of the bottom waters, as will shallow basins with poor water exchange.

In tropical seas, however, higher temperatures will accelerate rates of decomposition but exacerbate problems of eutrophication. Lam (1990) showed increased total volatile solids, total organic carbon, total nitrogen, and total phosphorus in benthic sediments in cage culture zones in Hong Kong, lower

dissolved oxygen content and increased ammoniacal nitrogen in the water column. These observations suggested that water pollution problems were imminent.

Excessive sediment deposition beneath sea cages results in the release of H₂S into the water, although no fish deaths appear to have been attributed to this (Beveridge 1987).

It is not known whether or not algal blooms which affected the Norwegian coastline in recent years could be attributed to seafarming, although it has been pointed out (Rosenthal et al. 1988) that pelletized feeds contain vitamin B₁₂ which is required for outbreaks of toxic red tides. There are moves in the salmon farming industry to reduce protein and phosphate contents of feeds to minimize eutrophication.

Where farms are stocked with filter feeders such as mussels, oysters, or milkfish, and the stock is dependent upon natural concentrations of phytoplankton for their feed, there will be clear limits to the density of stocks, beyond which the food supply will become depleted and growth rates retarded (Page and Ricard 1990). This will have negative effects on the farmed stocks and will also adversely affect other filter feeders in the surrounding community, with consequent effects on the community structure. In an extreme case, this could lead to severe impoverishment of an entire community.

In seapens, in which elements of the wild communities are excluded from an area, there will be a diminution of feeding grounds for benthic predators and some degree of alteration of the natural community. Likewise, heavily stocked seapens would have major impacts on the benthos, depending on whether or not the species being farmed utilized benthic food resources. If the farmed species was not a benthic feeder, elements of the benthos would enjoy protection from predators and, consequently, the seapen would function as a protected area; if it was a benthic feeder the benthos would be heavily overgrazed.

A third element in the ecological effects of seafarming is the physical alteration of the habitat by structures such as artificial reefs for sedentary organisms such as abalone, racks or stakes for bivalve cultivation, or seacages or pens. This leads to diversification of the habitat, and hence of the community, often with some adverse effects on water flow, particularly if fouling organisms accumulate on fences or meshes.

Poorly managed seafarms can serve as a source of pathogens and parasites, which can spread to natural stocks. Spread of pathogens between atolls resulting from careless transfers of spat has been reported in pearl oyster farms in French Polynesia, and the pathogens spread from *Pinctada margaritifera* to wild stocks of the same species and to *Tridacna maxima*, *Area ventricosa*, and *Spondylus varius* (Coeroli 1983).

Ill-considered chemical treatments, such as the use of Nuvan to control sea lice in salmon cages, have had adverse effects on adjacent populations of crustaceans. The use of wrasses in polyculture with salmon is now being advocated as a superior means of control.

For seafarming ventures which are dependent upon wild-caught fingerlings or fry, such as cage culture of grouper in Hong Kong, Malaysia, and Thailand or milkfish in many parts of Southeast Asia, recruitment to wild stocks will be reduced in proportion to the fraction of total stock of fry or fingerlings which are taken for seafarming. Taken to extreme levels, this would have a drastic impact on natural stocks and corresponding shifts in community structure. However, there is no evidence that this has ever occurred on such a scale in any stock.

ECOLOGICAL EFFECTS OF SEARANCHING

As in seafarming, the largest amount of information relates to salmon. However, their homing instincts for their natal streams make them rather a special case and there are no known instances of such precisely regulated homing instincts in tropical species. Consequently, the situation is much simpler in comparison with salmon, where hatchery-reared stocks, or escapees from seafarms, have been found to reduce diversity of genetically-unique local stocks (Windsor and Hutchinson 1990).

The success or failure of searanching rests upon three factors: the ability of the trophic resources of the community to sustain the additional stocks, the degree to which predators can be controlled, and the degree to which fishing mortality and size at first capture can be regulated.

In the case of the trophic resources, the prime consideration is whether or not the habitat is normally saturated with recruits each spawning season. If each nursery habitat is regularly filled with naturally-spawned recruits, attempts to enhance the stock will have no effect. This would apply in the most extreme cases to recruits with specialized habit requirements such as the *Panulirus argus* stocks of western Australia, in which the recruits occupy a restricted area of limestone reefs (Chittleborough 1970, Morgan et al. 1982).

In contrast, it can be argued that where larvae are widely dispersed in the oceans but will only survive if they drift to and settle onto a particular shallow water habitat, then that habitat is likely to be recruitment limited. This applies to many coral reefs where recruitment of a particular species to a particular reef appears to be a matter of chance (Doherty 1981, Munro and Williams 1985) and large variations in annual recruitment are apparently a normal occurrence (Sale 1976). Furthermore, it appears that in any aquatic community, recruitment is the major uncontrollable variable, being dependent on the coincidence of many favorable biotic factors. The degree of coincidence in turn regulates the size of the "survival window" (Bakun et al. 1982).

Addition of recruits to any system will exert additional pressure on the trophic resources with consequent reductions in the biomass of the prey and of any competitors. Likewise, the increased availability of recruits will benefit the top-level predators and could lead to progressive increases of the predators.

In any aquatic community, exploitation causes a progressive shift in the composition of communities. This shift usually involves both a relative and an absolute decrease in predatory species and increases in relative abundances of

species at the low end of the food chain (Munro and Smith 1985). Consequently, exploitation will lead to a greater degree of unutilized trophic resources, which will be recycled to detritus. For example, in a multispecies tropical fishery, the larger and more desirable predatory species such as snappers or groupers, are often targeted by a wider variety of fishing gears, their catchability is greater than that of a smaller species and the ratios of their natural mortality and growth coefficients (M/K) are lower; they are less resilient to heavy fishing than species such as penaeid shrimp with very high M/K ratios.

Thus, in a heavily exploited aquatic community the entire trophic pyramid is flattened. Stocking an apex predator might be ineffective if their prey species have been drastically depleted by fishing. It might be necessary to stock the prey species as well.

Two models are available for anticipating the effects of searanching. Polovina (1990) has presented modifications of both yield per recruit and surplus production models, which allow the numbers of hatchery-reared recruits to be factored into the calculations. By this means, the additional harvests that might be expected as a result of a searanching program can be calculated. However, a major assumption is that natural mortality rates will continue unchanged. Both of these models also yield estimates of the biomass which would be attained by the ranched stock. The biomass estimates, in turn, will permit the application of the Ecopath program (Polovina and Ow 1983, Polovina 1984), which, in its latest form, Ecopath II (Christensen and Pauly 1991), will enable the investigators to estimate the effect of the increased biomass of the target species on the rest of the community.

An additional possibility which has been done on a small scale in Japan with red sea bream (*Pagrus major*) is supplementary feeding of searanching fishes (Cowan 1981). When this is combined with luring fishes to feeding stations or to harvest sites with acoustic signals, the boundaries between searanching and sea farming become very blurred. However, there is no theoretical impediment to factoring the supplementary feeds into a trophic resource model.

INTRODUCTIONS OF EXOTIC SPECIES

One of the most potentially serious ecological consequences of Seafarming or searanching results from the introduction of alien species. Farmed species will inevitably escape and mass releases of an exotic species selected for searanching could have extreme effects on the natural communities. For example, coho salmon (*Oncorhynchus kisutch*) have been introduced to the northwest Atlantic. They were thought to be ecologically separated from Atlantic salmon but now there are concerns that they favor the same gravel beds for spawning. This results in the redds of the Atlantic salmon being disrupted and could result in the replacement of the more valuable Atlantic species by the less favored coho (Windsor and Hutchinson 1990).

CONCLUSION

An important corollary to all of the foregoing is that there is little point in attempting searanching in an unmanaged open-access fishery. All benefits would be marginalized by fishermen targeting the new stock.

Likewise, even in a well regulated system the degree to which the natural stocks are supplemented by hatchery-reared recruits should ideally be related to the strength of natural recruitment, with supplementary stocking being unnecessary on those occasions when an area is naturally saturated with new recruits. A recruitment monitoring program is, therefore, a necessary adjunct to a searanching program, both to maximize production and to avoid calamitous depletion of the trophic resources and consequent collapse of the target fish stock.

In the context of seafarming, careful planning with regard to siting of seafarms, optimizing inputs of feed, and minimizing inputs of chemical treatments will do much to mitigate the effects on water quality and on the ecology of the seabed.

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