14.10 Cage cultivation: a lousy system?

Intensive cultivation of any species is likely to encourage the rapid spread of disease or parasites. It is not surprising then that **sea lice** infestations are common in most coastal areas in which marine salmonid aquaculture occurs. Sea lice (*Lepeophtheirus salmonis*) are isopod parasites that feed on the blood of marine fishes. In salmonids, a parasite load of only 10 sea lice can lead to mortality of the fish as they migrate to sea. As cage-farmed fish are held in high density, the density of sea lice within the vicinity of the cages is also high. Concern has been raised that wild migrating salmonids (salmon and sea trout) are more susceptible to infestation as they pass close by salmon farms that are found on their migration route. This potential for elevated infestation rates has been linked by some to the decline in wild salmonid populations and has the potential to affect other salmonid species (Bjørn et al. 2007)

As in all intensive systems, cage-based aquaculture practices elevate the risk of the rapid spread of disease and parasites.

The loss of fish stock to sea lice infestation led to the development of chemical treatments that would kill the sea lice. However, these were limited to two main treatments: dichlorvos (an organophosphorus derivative now banned for use in the fish aquaculture industry) and hydrogen peroxide. The frequent and widespread use of these compounds led to reduced efficacy caused by resistance that developed in the sea lice. In more recent times, there has been a tendency to look to biological control methods. However, the latter require intense research and initial attempts to use goldsinny wrasse (*Ctenolabrus rupestris*) led to concern about their escapability and potential to act as vectors of disease. However, recent technological advances mean that the cultivation of the larger ballan wrasse, which is less likely to escape from salmon nets, is now commercially feasible (see Box Techniques box).

TECHNIQUES: Using cleaner-wrasse to remove salmon lice

Salmon farming is particularly important in Northern Europe which supplies 53% of the world market at present (FAO 2007). The majority of these fish are cultivated in cages located in coastal areas that are sheltered from adverse weather conditions. Salmon are vulnerable to attack by sea lice, which reduces the quality or even kills the fish if the infestation is heavy enough. Chemical treatments to remove the sea lice are associated with concerns regarding bioaccumulation of the chemicals in the final salmon product which are then passed onto humans although this is strictly monitored in some locations. In addition, the excessive use of chemicals in some localities has led to the development of pathogen resistance that necessitates the development of new chemicals or the use of increased doses of chemical treatment. This constant battle to eradicate sea lice in salmon farming is costly and potentially damaging to the immediate environment around the fish farm due to bio-accumulation and persistence of some chemicals such as dichlorvos.

Intensive research efforts have been made to examine the utility of so-called 'cleaner-wrasse' and attention turned first to try and utilize the goldsinny (*Ctenolabrus rupestris*). However, the small body-size of these wrasse means that they could escape from conventional salmon nets and possibly act as a vector for any fish pathogens ingested by the sea lice consumed during the 'cleaning' process. As a result, commercial farmers initially were concerned that the wrasse could spread disease and parasites from one farm to another (Costello et al. 1994; Gibson & Sommerville 1996). A simple solution to the wrasse escapee problem is to use smaller meshes on the salmon cage but these might impede water flow and could also incur a greater biomass of fouling biota on the net meshes.

The solution might be to turn attention to the use of a larger body-sized wrasse species, such as the ballan wrasse (*Labrus bergylta*). However, the development of a wild-capture fishery for ballan wrasse would hardly be a sustainable solution to providing the cleaner-wrasse needed for the salmon industry, hence a new programme of research to develop the scientific knowledge to rear these fish on a commercially viable scale was required. Below, aquaculture specialist Anne Berit Skiftesvik, leads us through the technological and scientific challenges that had to be overcome to understand how to rear this fish on a commercial scale.

What was the driver to focus on ballan wrasse and not some other species?

It was known from anecdotal accounts that the wrasses would pick lice off the sides of salmon. Therefore, early on in the quest for the 'best' wrasse species to use, several species were tested and the ballan wrasse proved itself an effective lice-picker. Further, ballan wrasse are large enough to be co-cultured with larger salmon (smaller wrasse would be eaten by the salmon) and are large

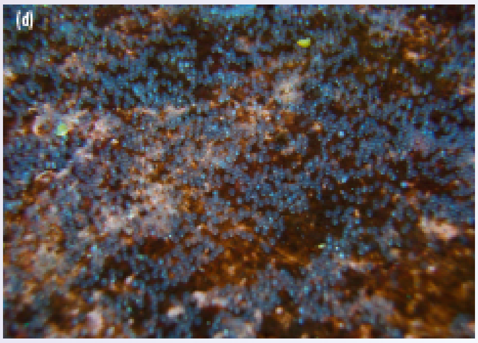
enough so that a reasonable mesh size can be used in sea cages (the mesh size must be matched to the size of wrasse used to prevent their escape; however, small mesh sizes are not practical). Ballan wrasse continue to pick lice at lower temperatures than other species (which greatly extends the geographic range over which they can be used effectively, particularly northward). Ballan wrasse are also more robust than other species.

When considering a new species for culture, what are the first things you need to understand?

You need to know as much about their natural ecology (and behaviour) as possible, particularly the ecology of the reproductive adults and the early life-stages and the physical environment that they live in. To accomplish this for ballan wrasse, we undertook a series of projects that aimed to characterize their spawning habitat and their spawning behavior in the wild (using underwater video cameras). The information gained in these projects formed the basis for our first attempts to culture the species.

For ballan wrasse, what turned out to be the major challenges to cultivating them successfully and how did you solve them?

The amount of space that ballan required for their spawning behavior displays was difficult to assess and was at first underestimated (i.e. size of the tank; water depth). The number of males in the brood-stock holding tank must be matched to the space available so that males can establish territories. The fish must be provided with structure in which they can hide (e.g. macrophytes simulated using shredded black plastic garbage bags). Wild brood-stock had to be given enough time to acclimate so that they were not stressed in captivity or by the frequent appearance of humans. Artificial spawning substrata must be provided (e.g. pieces of carpet) for the adults to play out their spawning dance over and onto which the eggs can settle and adhere. These artificial substrata must then be removed from the brood-stock tank and placed in egg incubators. The eggs must be removed from the tank because: (1) larvae would be flushed out of the brood-stock tank and cannot be cultured in that environment and (2) if the eggs are not removed from the brood stock tank, the males will invest energy to protect them and will not continue spawning. There proved to be a minimum temperature below which egg development was poor. Larvae of the ballan wrasse were quite fussy and required live feed for a relatively long time compared to other marine species and a specially-formulated diet was required at weaning to obtain good survival results. Larvae did not perform well in terms of growth and survival under the fluorescent



lighting typically used in hatcheries. Better results were obtained when the larvae were cultured under natural light (in a facility with a transparent roof) and later using lamps with a spectral output that is closer to natural sunlight (note that ballan wrasse eggs are deposited in shallow illuminated water in the early summer).

Are there any other technical issues that need to be overcome to make ballan wrasse a viable proposition?

Reducing the duration of the period during which the larvae require live feed would help to reduce the cost of cultivation. Improving weaning success in the transition from live feed to formulated diet. Improving the nutritional quality, taste, and palatability of the formulated diet (specific to this species), as this would increase growth, survival, and reduce waste. Improving the culture tank environment so that it is better-suited to the specific requirements of ballan wrasse larvae and early juveniles (e.g. flow, depth, structure, shelter). If ballan wrasse are to be used with salmon, the nets on salmon farms must be kept much cleaner of fouling organisms than would normally be required. This is because the ballan wrasse will, naturally, eat the food that is easiest to get. Cleaner nets encourage them to eat more sea lice.

Do ballan wrasse provide an effective solution to the salmon lice problem?

Ballan wrasse can be very effective in keeping sea-lice infestation under control (particularly egg-bearing female lice) throughout the on-growing period—at a stocking density of only 1% that of the salmon. It is important to emphasize here that wrasse are continuously eliminating lice, whereas other treatments are short-lived and must be repeated at regular intervals (which is much more invasive and damaging to the salmon, and the environment). The lice can never develop resistance to this form of control (as they do to chemicals). Also, wrasse can be used even if the salmon are ill or in poor condition (a situation that makes the use of chemicals impossible—that would result in mass mortality). Nonetheless, wrasse must be viewed as one part of a multi-pronged approach to controlling salmon lice (e.g. some topical chemical treatments; lice traps; vaccination) since they will never completely eradicate the parasite.

14.11 Breaking away from the coastal margin

With the ever-increasing demands on the coastal margin, the prospects for the expansion of suspended-cage cultivation is finite. This has led to research into alternative technologies for intensive marine fish cultivation. Two developments are most noteworthy: the development of **offshore automated** fish cages and the development of recirculation systems. Automated fish-cage systems are a recent development in the last decade (Fig. 14.6). The essential features of these systems are that the fish are fed automatically, they can be lowered to the seabed such that they are beyond the effects of wave action and cause less of a navigation hazard to shipping, and they can be resurfaced for repair, maintenance, and harvesting (Dahle 1995) (Fig. 14.6).

To find out more about offshore fish farm cultivation visit http://www.oar.noaa.gov/spotlite/archive/spot_hawaii.html.

Recirculation systems present the most sophisticated level of current aquaculture rearing techniques. Enclosed tank and raceway systems have been used to cultivate marine fish for a number of decades, but in the past they have been restricted to coastal locations by the necessity to pump a sufficient through-put of seawater. This incurred costs, both from the pumping of water and, in some cases, the need to heat it when warm-water species were cultivated in temperate areas. With the development of recirculation systems, the cultivation of marine species is no longer tied to locations adjacent to the coast (Fig. 14.7). In addition, non-indigenous species can be cultivated as there is no risk of accidental introductions into