

The Release of Pest Species by Marine Aquaculture: Lessons from a South African Parasite Introduced into California Waters

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ABSTRACT: A South African worm accidentally introduced into California abalone farms can infest, weaken and deform the shells of abalone and other native California marine snails, reduce growth and reproductive rates, and leave the host species more vulnerable to predation and environmental hazards. The worm was spread to all California abalone farms via stock transfers, has bankrupted some growers, and has infested native snails in the ocean in at least one site. Despite the potential for substantial harm to California's marine resources, the state continues to allow abalone farming practices that can release this parasite into the environment.

Marine aquaculture in general is inadequately regulated to prevent the introduction of harmful exotic organisms. To avoid such impacts, aquaculture should be governed by the following principles:

- Aquaculture facilities should be required to operate in a sustainable manner without causing harm to the marine environment, which includes not releasing exotic organisms.
- Aquaculture should be based on native, local stock whenever possible. Imports and transfers of stock should be minimized, thoroughly inspected, and quarantined for an appropriate observation period.
- Aquaculture stock infested by parasites should be isolated from the environment. If isolation is impossible, the stock should be destroyed.
- Proposals to import exotic stock should receive full public review, and advisory bodies should include all relevant stakeholders, not just the aquaculture industry.

Aquaculture activities have a long history of introducing harmful parasites and diseases of fish and shellfish into various parts of the world (e.g. Farley 1992; Brock 1992; Mills *et al.* 1993; Barber 1996; Smolowitz 1996). Outbreaks of diseases and parasites are common in the crowded and often stressful conditions of aquaculture facilities (Huner and Brown 1985). In some regions, parasites or diseases accidentally imported by aquaculture have had devastating effect on native fish and shellfish populations (e.g. Mo 1994). Preventing such introductions in the future will require both better regulation of the initial importing of organisms, and better controls on the release into the environment of undesirable organisms that are cultured or that become established within aquaculture facilities. The recent importation and establishment of a harmful

shell parasite in California abalone farms, and its subsequent release into the environment, suggests that there is substantial room for improvement in the regulation of marine aquaculture.

THE ABALONE PARASITE

In the early 1980s the exotic sabellid worm *Terebrasabella heterouncinata* (Fitzhugh and Rouse 1999), then unknown to science, was accidentally introduced into California abalone farms with imported South African abalone, *Haliotis midae*.¹ The worm established infestations in the shells of the California Red Abalone, *Haliotis rufescens*, the species cultured in California. Intense infestations produced

¹ It is unclear whether the abalone were imported with the knowledge of California agencies.

shells that were easily broken, disproportionately tall relative to the size of the aperture and foot, and frequently lacking respiratory holes. In addition the growth of soft tissue was slowed or halted. Overall, such infestations produced abalone with reduced reproductive potential and, were they to occur in the natural environment, greater vulnerability to predators and to dislodging or damage by waves or rock movement in the surf zone. Kuris and Culver (1999) found that these worms can infest not just Red Abalone but probably all species of California abalone (all of which are in decline and one of which, the White Abalone *Haliotis sorenseni*, is thought to be near extinction—Tegner *et al.* 1996) and a wide variety of native California marine snails.

As is common in some types of aquaculture, abalone stocks were frequently transferred between facilities, spreading the South African worm to all California abalone farms by the mid-1990s, with the resulting infestations bankrupting some growers. In 1994 researchers determined that the problem was caused by an exotic parasite, by 1995 they had demonstrated that it can infest a broad range of marine snails, and by 1996 the worm had been found in native snails in the ocean in at least one site (Kuris and Culver 1999).

THE GOVERNMENT RESPONSE

The California Department of Fish and Game (CDFG) is the state agency with the primary responsibility for managing and regulating aquaculture and for protecting the marine environment. However it also has a potentially conflicting mandate to promote and encourage the development of the California abalone farming industry.

CDFG took no action to prevent the release of the sabellid worm into California waters until December 1996,

when CDFG notified abalone farmers that it would take the following steps (CDFG 1996):

- (1) Stop the direct out-planting of abalone into California waters.²
- (2) Require the installation of screens on the pipes that discharge water from on-shore abalone farms into the ocean; and require growers that rear abalone in cages and barrels in the ocean to stop dumping empty shells, kelp and other debris that could harbor sabellid worms into the ocean.
- (3) Require abalone farmers to notify CDFG when abalone are being transferred between facilities, so that CDFG can inspect the shipments for sabellids.
- (4) Not issue 1997 aquaculture registrations, which are needed in order to operate aquaculture facilities in California, to any abalone farms that do not have an approved plan for eradicating the sabellid worm.

While these are useful steps in concept, they did not go far enough, nor were many of them implemented effectively.

For example, screening the discharge pipes from on-shore facilities should help to prevent the release into the ocean of shell debris containing adult worms and of live gastropods infested with worms, but would still allow larval worms to be discharged into the ocean. The sabellid larvae are not planktonic, but rather disperse by crawling short distances on the shells of their host species or on other benthic substrates. However, they can be dislodged with aeration or when tanks are flushed, and float free in the water column (K. Ruck, pers. comm.; C. Culver pers.

² Large numbers of cultured abalone, numbering at least in the tens of thousands and presumably including a significant number of sabellid-infested abalone, were planted in the ocean over several years to augment the declining abalone population. These plantings were made under Private Stocking Permits issued by CDFG, but in most cases the descriptions of the sites are too vague to enable them to be checked for sabellid infestations, and the records were retained for only three years (CDFG 1997).

comm.). A small number of sabellid larvae were collected in the discharge from an infested abalone farm (C. Culver pers. comm.) which, based on the relative volumes of water sampled and discharged, works out to over 70,000 larval worms per day carried in the discharge from this one farm (C. Friedman pers. comm.).³ The screens installed on discharge pipes typically have a mesh size of 1 cm or larger, while the sabellid larvae are about 0.05 mm in diameter, so the screen openings need to be made about 200 times smaller if they are to catch sabellid larvae (K. Ruck pers. comm.). Furthermore, growers are allowed to rear infested abalone in cages or barrels in the ocean, with mesh or holes large enough to freely release larvae into the environment (C. Culver pers. comm.).

Effective inspection of all transfers of abalone stocks is essential to containing and ultimately eliminating the sabellid worm from California abalone farms, but unfortunately current procedures do not appear to be adequate for this job. For the inspections a number of abalone are randomly selected and shucked, and the shells are examined for sabellid worms. The more shells examined, the greater the chance of detecting an infestation, but CDFG's protocols only require the examination of 60 abalone per population unit (defined as a tank, barrel or year-class), which can include up to 9,000 abalone or more (P. Kalvass pers. comm.). Even if the individual examinations produce no false negatives (that is, if there is even a single sabellid worm in the shell

of an examined abalone, it will be detected), then examining 60 shells per unit leaves about a 5% chance of missing a 5% infestation rate (meaning that one abalone out of 20 in the shipment has sabellids) and about a 55% chance of missing a 1% infestation rate (C. Gowan pers. comm.) In at least one recent case, a shipment that passed inspected did contain sabellids infested a previously "clean" abalone farm, which shortly thereafter shut down.

While requiring abalone farms to develop eradication and control plans is an important step, the content of those plans is also important. Several growers have proposed to eliminate the sabellid worm from their facilities by selling off their infested abalone. This would essentially transfer the problem out of CDFG's jurisdiction without eliminating the risk, since the sabellid worm could then be released into the ocean via unscreened discharges from the holding tanks of live seafood distributors or retailers, or by discarded shells. Furthermore, although CDFG said at the end of 1996 that it would not provide aquaculture registrations to abalone farms that did not have approved eradication plans, it has allowed abalone farms to continue operations even though no plans have yet (as of spring 1998) been approved.

CDFG is not the only government agency with the responsibility and authority to address this problem. The U. S. Environmental Protection Agency and California's Regional Water Quality Control Boards are responsible for regulating discharges of pollutants, including biological pollutants such as exotic species, under the Clean Water Act (Cohen and Foster 2000). Other agencies charged with protecting the coastal marine environment or marine organisms may have additional obligations and powers to

³ It is unclear whether the larval worms collected came from the abalone farm itself, or from infested snails living in the discharge channel. However, in either case the data demonstrate that the discharge streams are capable of carrying large numbers of sabellid worms into the ocean, and may in fact be doing so. If the larvae did originate in the abalone farm, the number discharged may have been six times greater a year or two earlier, when the number of infested abalone was that much greater (R. Fields pers. comm.). Sabellid larvae have also been collected from abalone tank outflows in South Africa (K. Ruck pers. comm.).

prevent the introduction of this harmful parasite.⁴ None have taken steps to do so.

PRINCIPLES FOR MANAGING MARINE AQUACULTURE

Such lapses are unfortunately not confined to the sabellid worm problem or to the abalone industry. Marine aquaculture in general is inadequately regulated to prevent the introduction of exotic organisms into the environment, and in many parts of the world aquaculture activities have imported and released parasites, diseases, predators or competitors of native fish and shellfish. To reduce the risk of impacts to important marine resources and the marine environment, the development and management of marine aquaculture should be based on the following principles:

- Aquaculture facilities should be legally required to operate in a sustainable manner, without causing harm to marine resources or ecosystems, which includes not releasing exotic organisms into the environment. Aquaculture operations that cannot meet this standard should not be encouraged or allowed.
- Whenever possible, aquaculture should be based on native, local stock. Imports of stock and transfers of stock between regions should be minimized, and whenever possible the stock should be transported in the egg or larval stage. All imported and transferred stock should be thoroughly inspected, and held in quarantine (in isolation from the environment and

from other stock in the receiving facility) for an appropriate observation period.

- Any stock infested with exotic organisms should be immediately isolated from the environment. If isolating the stock is not feasible, the stock should be destroyed and properly disposed of. Any parasites or disease syndromes found in aquaculture stocks that are not known from the local environment should be managed as if they were exotic organisms until proven otherwise—that is, stock infested with such parasites or diseases should either be isolated from the environment or destroyed.
- Proposals to import exotic organisms for culturing should receive full public review. Participation on government advisory bodies or committees that address the management or regulation of aquaculture should include all relevant stakeholders, not just the representatives and consultants of the aquaculture industry.

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⁴ For example, the National Marine Fisheries Service is responsible for protecting marine species listed under the federal Endangered Species Act from harmful actions which can include "releasing non-indigenous...species into a listed species' habitat or where they may access the habitat of listed species;" and the California Coastal Commission is charged by the California Coastal Act with maintaining marine resources and ensuring that uses of the marine environment are carried out in a manner that will "maintain healthy populations of all species of marine organisms" (Cohen and Foster 2000).

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