Do we have the vision to integrate our marine aquaculture?

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A DRAFT POLICY FOR THE DEVELOPMENT OF A sustainable aquaculture industry in South Africa was released recently by the Department of Environmental Affairs and Tourism.[1] This brief proposal is the starting point for a comprehensive national aquaculture programme. The preamble mentions the disappointing statistic that South Africa accounts for less than 1% of African aquaculture production, which in turn is less than 1% of global output. Worldwide, aquaculture production grew by an average of 8.8% a year between 1950 and 2004, to 59.4 million tons in 2004, worth more than US$70 billion.[2] This growth has been widely explained as a response to the incapacity of global capture fisheries to expand seafood production over the last two decades, which, given the rise in world population, has led to a reduction in seafood consumption per head.[1–3]

The geographical spread and species exploited in aquaculture are, however, both extremely different from those of traditional capture fisheries. Nearly 70% of world aquaculture takes place in China, and a further 22% in other Asia-Pacific countries.[2] Of the top 10 farmed aquatic species (over 1 million tons annually), five are species of carp (freshwater fish), three are seaweeds [Japanese kelp (*Laminaria japonica*), nori (*Porphyra* species), and wakame (*Undaria pinnatifida*)], and two are molluscs.[2,3] Seaweeds constituted 23.4% of world aquaculture production in 2004; as marine aquaculture makes up 51% of global aquaculture, seaweeds represent an impressive proportion by weight of the marine species harvested.[2]

Over 90% of marine aquaculture production is seaweeds and molluscs.[3] Most of the seaweed collected is for human food; indeed, a major success in the retail trade in the West is the remarkable spread of sushi restaurants. In South Africa, however, seaweeds are currently eaten only by the wealthier section of the population.

In the western world, including South Africa, finfish species for human consumption are generally thought of as primarily those which are high in the food chain—species which could be considered as 'supercarnivores' (such as salmon, tuna, hake, and snoek). This has given rise to a phenomenon that has been referred to as 'fishing down the food web'.[4,5] It is apparent that most of the capture fishery production globally, in the last few decades, is composed of small fish, with 9.7 million tons of the Peruvian anchovy ('anchoveta') being by far the top yield in 2002.[3] Around half of world capture fish production is not used for human food, but for the manufacture of fish meal and fish oil.[3] Nearly half (46%) of this fish meal and 81% of the fish oil are used in the preparation of feed for the aquaculture industry.[6] The marine aquaculture success story of western Europe has been the salmon. Although the region contributes only 3.5% of world aquaculture production, it harvests 55.6% of farmed salmonids[2] (salmon and brackish-water/marine rainbow trout), with most of the rest being from Chile.[6] The world price of salmon has been dropping steadily over the last 20 years, as has the price of feed, with increased efficiency in both industries.[6] There is evidence, however, that salmon farming, generally carried out in cages in sheltered fjords or sea lochs, is becoming financially less viable, with feed costs dropping at a slower rate than the sale price of the fish.[6]

Why are seaweeds so important to marine aquaculture?

If the rich world clearly prefers carnivorous finfish, why, then, is world aquaculture overwhelmingly dominated by carps, seaweeds and molluscs, with the latter two groups dominating marine aquaculture? The reason is surely that species lower in the food chain are easier to grow, and can be raised more efficiently, by simple methods. Agriculture has developed over millennia, and the species we harvest are plants, herbivores and omnivores. Although large-scale aquaculture is a much more recent phenomenon, the pattern is largely the same.

The 'pyramid of productivity' is a basic premise of ecology, with most biomass in ecosystems represented by primary producers, and progressively less production the higher up the food chain. Seaweeds and filter feeders are farmed because they are nutritious, tasty and relatively easy to grow. The ease of cultivation is why the economies of coastal villages in Zanzibar, for example, have been transformed, not by growing their traditional capture fish, but by aquaculture of the red seaweed, *Eucheuma,* which is sold abroad for carrageenan production.[7]

For decades, Chinese fish farmers have been raising various species of carp, with different dietary requirements, in a single-pond system.[8] An extension of this practice has lately been described in the scientific literature as 'integrated multi-trophic aquaculture' (IMTA).[9–11] The breeding of carnivorous finfish in monoculture is very wasteful. For example, only 15–20% of fed nitrogen goes into aquacultured Mediterranean seabass, whereas 60–86% is released, generally into the environment, as dissolved nitrogen, and 6–15% as particulate organic nitrogen.[12] Seaweeds obtain their nitrogen from dissolved nitrate and ammonia, and filter-feeding molluscs from food particles. It is therefore logical to separate 'fed' aquaculture from 'extractive' aquaculture.[10] Moreover, it is noteworthy that IMTA has the potential to treat this excess nitrogen from fish farms not as a problem but as a resource.[10,13] There is a rather small international group of scientists conducting research on this topic, however, whereas international aquaculture conferences are dominated by fish biologists.[14]

Why is South African aquaculture production so low? The main reason, although it is seldom stated, is that we do not have the water to support it. Fresh water is in short supply, and we have extremely few sheltered-water marine sites available for aquaculture production. The success story of South African marine aquaculture is the abalone (perlemoen, *Haliotis midae*),[15,16] described in a recent FAO report as a 'niche species'.[2] An estimated 890 tons was raised in 2006 by 13 farms, with around 10 more in development (W. Barnes, Abalone Farmers Association of South Africa, pers. comm.). This output is land-based, in tanks, and the abalone is exported mainly to the Far East. While the high price of abalone on the global market is clearly critical to this success, I offer the opinion that another reason for the success of the industry is

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that the abalone is low in the food chain.

Haliotis midae is a herbivore that eats seaweed. Most of the farms are situated west of Cape Agulhas, where kelp harvesting provides the main food source.[16] Two farms on the southeast coast, where there are no kelp beds, are currently growing a considerable proportion of their own feed, by culturing the green seaweed *Ulva* (the sea lettuce), and to a lesser extent the red seaweed, *Gracilaria,* in abalone farm effluent. Most production is in oval raceways, with water motion driven by paddle-wheel. In addition, a producer in Gansbaai has built a large new extension to the farm, where the abalone effluent is fed into a series of *Ulva* raceways, and about half the water is recycled back to the abalone tanks. This system was commissioned in January 2006, resulting in significant internal feed production, but also a reduction in pumping costs, as well as a rise in temperature, which increases growth rates in the abalone tanks. Thus, three abalone farms in South Africa are currently practising commercial IMTA. This is extremely rare outside Asia. In fact, as there are around 40 of these seaweed raceway ponds currently in operation, and each is reported to produce an average of 2 tons of *Ulva* each month, it is possible that, at an estimated 960 tons, in 2006 the largest South African aquaculture product, by weight, was the sea lettuce. These figures are unlikely to appear in summaries of local aquaculture data, however, as the seaweed is consumed internally on the farms and not sold.

Growing species low in the food chain in marine aquaculture operations makes ecological sense and is likely to bring economic benefits in the long term. There are several pilot projects under way to develop the aquaculture of local marine carnivorous finfish. These should be encouraged, but problems are likely to arise when scaling up, because of the lack of sheltered coastal waters for easy production, or the cost and potential environmental problems of raising carnivorous fish on land. Policies are in various stages of preparation on different sectors of the aquaculture industry (covering finfish and molluscs, for instance) and it is important that the new draft sector plan[18] includes a paragraph on integrated aquaculture, especially as it is already happening.

In some European countries, there are already financial benefits being gained, promoted by government agencies, from the environmental advantages of practising extractive rather than (or linked to) fed aquaculture. Does the South African aquaculture industry, in collaboration with scientists and policy makers, have the insight, vision and ability to integrate our marine aquaculture in the same way?

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Integrated aquaculture on an abalone farm on the southeast coast of South Africa, with the abalone tanks under shade on the left. The paddle raceways grow the green seaweed *Ulva*, for feed, in abalone effluent. Photograph: R.J. Anderson.