APPLICABILITY OF ORGANIC PRINCIPLES TO MARINE FINFISH CULTURE: COMPARING OPEN OCEAN NET PENS TO CLOSED-CONTAINMENT SYSTEMS FOR PRODUCTION OF KONA KAMPACHI® *Seriola rivoliana*.

Neil Anthony Sims

Kona Blue, P.O. Box 4239, Kailua-Kona, HI 96745 (email: neil@kona-blue.com)

INTRODUCTION

The McCarthyism of mariculture

The McCarthyism of mariculture is no sound basis for discerning appropriate Organic standards for farming fish. Anti-aquaculture activists, in earlier testimony to the NOSB, have sought to stigmatize all net pen culture, or all farming of 'carnivorous' fish as inherently ecologically destructive, and universally antithetical to Organic principles. Some anti-aquaculture opponents have resorted to outright lies. Past testimony to the NOSB has, for example, asserted that our Kona Kampachi® ocean culture operation in Hawaii yields food conversion ratios (FCRs) of 50:1. The truth, however, is that FCRs in our offshore net pens are around 2:1.

Yet to be opposed to aquaculture is akin to being opposed to agriculture; and opposition to net pen farms is comparable to opposition to the fencing of ranchland. It is rarely a system that is fundamentally flawed. Rather, some systems, if inappropriately applied or practiced, can cause ecological detriment. The same strident smearing of marine fish net pen culture could equally be said of cattle ranching or corn crops – if practiced badly, then there can be negative consequences. However, it is through the establishment of Organic principles that we seek to encourage more sustainable practices for such farming systems. Organic beef and Organic corn encourage better, more environmentally sound farming practices in the same way that Organic marine fish farming should.

The *Salmo*-centricity of the debate

Much of the debate over net pens has been overly emotional, driven primarily – as it appears to be - by a deep abhorrence for the farming of Atlantic salmon. Atlantic salmon usually dominate any discussion of net pen production systems. This species is predisposed to domestication by virtue of its rapid growth rate, its ease of culture in the hatchery (with a large yolk, salmon can be readily weaned directly onto dry pellet feed), and its broad recognition in the market. The oceans, however, constitute more than 70% of the planet's surface area, and may contain more than 20,000 different species of fish. Whereas there has been around 10,000 years of mankind's selection, adaptation and refinement of terrestrial livestock culture, marine fish culture has only been initiated on any scale in the last 30 years.

But the NOSB is not trying to determine, here, the appropriateness or otherwise of Organic culture of one anadromous species, even if that species presently does dominate the debate – and the seafood retail counterspace. We are instead here to consider whether Organic principles can and should be applied to a specific culture system. One may detest sheep ranching, and find much at fault in the global wool production system, but that bias should not exclude all livestock from the potential to be cultured in an Organic, sustainable, environmentally sound manner.

Salmon farm opponents often portray net pens as sea lice (*Caligus* spp) proliferation points, inferring that sea lice infestations have negative impacts on wild salmon runs. This has been cited by some anti-aquaculture activists as further reason for excluding net pens from Organic certification. Yet the presence of pests or parasites, *per se*, is not anathema to Organics; indeed, much of the Organic theory strives to find a natural balance with pests and parasites. Salmon farm opponents would suggest that closed containment systems are more appropriate for Organic fish farming than open net pens. Yet closed containment systems – either land-based tanks or enclosed pens - are viewed by fish farmers as more costly, unproven technology – akin to growing chickens on a boat. (Yes, you can probably do it, but it doesn't make sense, and it probably won't make money.) Closed containment systems also appear, at first glance, to be closer in kind to the "feed lots" that are so often derided by anti-aquaculture activists.

The process for setting Organic standards must rise above the prejudices of anti-aquaculture activists that are really just opposed to this one, single species. Organic standards should instead address the potential for culture of the full diversity of marine finfish species, in both open ocean net pens and closed containment tanks.

<u>The historical arc of net pen farming of marine fish</u>

There are, indeed, some substantive concerns with the potential environmental impacts of net pen culture. Past primitive efforts – 20 or more years ago – had little understanding of the interplay of culture systems and the marine environment, and were severely limited by the science available in net pen engineering, fish nutrition, feed technology and ecosystem modeling. Earlier net pen systems were often poorly constructed, and needed to be sited in more protected bays and fjords, where water circulation was inadequate, and where wastes accumulated on the substrate beneath the pens. The wet fish or moist pellet diets that were used previously had low digestibility, compounding effluent issues, and use of prophylactic antibiotics was not uncommon to promote growth or compensate for poor fish nutrition or welfare.

Over the last two decades, however, marine fish culture has made vast improvements in farm siting, ecosystem modeling, net pen engineering, feeds production and fish nutrition. Stronger, more dynamic net pens and mooring systems now allow farms to be sited in deeper waters, with better circulation and readier assimilation of effluents. Dry pellets have increased digestibility of diets and reduced feed conversion ratios (FCRs), with corresponding improvements in effluents and fish health. Marine fish veterinary science has also reached a level of sophistication that allows broader ecosystem impacts to be considered, as well as better, proactive management of fish health and welfare.

Kona Blue considers our sashimi-grade Kona Kampachi® (*Seriola rivoliana*) a potential candidate for Organic culture. Our pioneering offshore farm currently produces around 18,000 lbs per week of healthful product: high in nutritious fats, including Ω-3 fatty acids, yet containing no detectable mercury. We also strive for more sustainable feed solutions: we have reduced fishmeal and fishoil in our fish's diets by, respectively, 50% and 25%, compared with the previous 'organic' rations (based on European standards for fish feeds, which relied on "the most natural diet possible – i.e. anchovies). Our open ocean net pens are also located in areas with strong currents. The high rates of water exchange maintain ideal water quality, resulting in excellent fish health, and low levels of physiological stress.

These rapid improvements across the industry, however, are rarely acknowledged by fish farming opponents. So how can the NOSB reach an informed decision in such an emotionally-charged debate where untruths of more than an order of magnitude are bandied about in public testimony, and where there are diametrically-opposed perspectives on the past history, recent progress and future growth potential for this industry? This paper attempts to present a broader perspective, beyond salmon, based on our experience culturing Kona Kampachi®, both in land-based and open ocean culture systems. The applicability of Organic principles to each culture system is assessed, and recommendations from the Aquaculture Working Group (AWG) are reviewed in light of our experience.

METHODS

This presentation compares and contrasts two grow-out systems for marine finfish – land-based tank culture and open ocean net pen culture - as potential Organic production methods. During the pilot-scale and market testing period of Kona Blue's development (2001 – 2004), the company operated eight 50,000 L HDPE-lined steel tanks in a land-based production system at the hatchery/research facility, on land rented from the Natural Energy Laboratory of Hawaii Authority (NELHA). At the same time, Kona Blue was applying for the permits and the requisite lease under Hawaii state law to operate a larger-scale open ocean net pen farm in the waters offshore from NELHA. After more than three years of consultation and consensus-building with the local community, State and Federal regulatory agencies, these permits and lease were finally approved in 2004, and operations offshore began in February 2005. We now have more than thirty months operating experience in the offshore environment – a comparable time period to that for the land-based production system.

Environmental monitoring offshore has included assessment of water quality, benthic habitat (immediately below the net pens, around the edge of the lease area, and on the pristine coral reef along the coast-line, directly inshore of the farm site), as well as monitoring of wild fish health and marine mammal interactions. This comparison presents both qualitative and quantitative assessment of the environmental impacts and other factors, including biological loading and stocking densities, effluent fate and nutrient recycling, energy usage and carbon footprint differential, animal welfare and broader ecosystem impacts.

RESULTS

1. Biological loading and stocking densities

The production capacities, biological loadings and stocking densities of both land-based and open ocean net pen systems are presented in Table 1. The original site use and site preparation descriptions are also presented, to provide some context for consideration as to which method is the most “natural”. The lava fields at NELHA support little in the way of plant or animal life, and so there is no great ecological loss from leveling of the lava for tank installation. In other locations, however, land-based site preparation may require clearing of forest, pastureland or mangroves in watershed or wetland areas.

Construction impacts for the offshore net pens are minor in both the area impacted, and the duration. Mooring grids for open ocean net pen operations can be secured either by pins or embedment anchors. Pins are usually only single points drilled into hard benthos. The potential impacted area is very small, and the perturbation is only temporary. Embedment anchors, as used in soft substrates of sand and mud, may require some dragging to position correctly, but such physical impacts are only small in area and time, and once established, their footprint is small.

Table 1 :

Production capacity and biological loading of land-based tank system and open ocean net pens.

	LAND-BASED TANKS	**OPEN OCEAN NET PENS**
Original site	Lava field	Open ocean
Site preparation	Bulldozer and gravel crusher	Mooring grid
Construction	Steel frame with HDPE liner, PVC pipe and drains	Sea Station™ steel frame on Dyneema (Kevlar®) netting
Number of units	Eight (8)	Eight (8)
Unit volume (L)	25,000 (Note 1)	3,000,000 (Note 2)
Total capacity (L)	200,000	24,000,000
Mean density (kg/m^3; Note 3)	25	15
Mean standing stock (kg)	5,000	360,000
Water exchange (turnovers /hr)	0.25	60 (Note 4)
Flow-rate (L/hr)	6,250	720,000,000
Loading (Kg/L/hr)	0.8	0.0005
Annual production capacity	10,000 Kg/yr	720,000 Kg/yr

Note 1: Although tanks have a capacity of 50,000L, because of inadequate seawater pumping capacity they could only be operated at half-volume. Operating at the higher volume would have halved the water turnover time from 4 hours to 8 hours, with consequent negative impacts on water quality.

Note 2: Kona Blue has recently applied to the State of Hawaii for a doubling of capacity at its existing site, by doubling of the volume of each of the net pens to around 6,000 m^3.

Note 3: Mean density of fish is calculated as half of the target maximum density: i.e. half of 50kg/ m^3 for the land-based tanks, and 30 kg/ m^3 for the offshore net pen operation.

Note 4: Turnovers per hour in the land-based system is calculated on the basis of 6 turnovers per day in each of the 8 tanks. Offshore water exchange rate is calculated using an average current speed estimate of 10 cm per second (6 m per minute). Average distance through the cage is around 20 ft, or 6 m, as the maximum diameter is around 80 ft, and diameter diminishes both away from the central spar, and further from the equatorial rim.

The volume of water and the water turnover (exchange rate) are far higher in the offshore system than in the land-based system. The mean density of fish in the land-based system is 67% higher than in the offshore system; such high densities are essential in land-based tanks to help pay for the capital and operating costs. In the offshore net pens, lower mean densities can be used, as the production capacity is much greater, and operating costs are lower.

Figure 1 : An underwater photograph of the author SCUBA-diving outside a submerged Sea Station® net pen, in waters off Kona, Hawaii. The top of the net pen is around 30 ft below the water surface. The overall water depth is around 220 ft (65 m). The net pen is stocked with around 50,000 Kona Kampachi® (*Seriola rivoliana*), which were around 1 kg (2 lbs) in size. The innate schooling nature of the fish is clearly evident, with most of the fish bunched in the sector of the net pen closest to the camera. (Copyright: Doug Perrine, SeaPix).

In oligotrophic oceanic waters, nutrient input is also a source of productivity, rather than pollution. Open ocean net pen structures can also enhance species diversity. Baitfish (upper right hand corner of the figure) and large pelagics are attracted to the structures, in what is otherwise empty ocean.

The health and well-being of the fish in each culture system can only be subjectively assessed. The 1,600 x greater biological loading, and the 67% greater maximum density in the land-based tank system may have some less humane element, but Kona Kampachi® in both systems did not display any signs of crowding stress. Fish have been noted to often school densely in net pens, even when there is other available space (Figure 1). The open net pen system, however, is significantly closer to the natural environment, and the native habitat of the fish. Fish offshore experience natural lighting, seasonal changes, tides and currents, and are separated from the offshore environment – and other fish - only by the Dyneema® (Kevlar) mesh of the net pen. The fish at Kona Blue's site are also more than 100 ft away from the substrate. (The bottom of the net pen is around 85 ft deep; the water depth around the cages is over 200 ft deep). The net pens are over 80 ft in diameter, and 55 ft deep. (The larger net pens proposed for the site are over 105 ft in diameter). Fish swim freely inside the net pen, often moving together in a school (Figure 1), or following their individual inclinations.

The land-based tanks, however, were far less natural an environment for Kona Kampachi®. The tanks only 3 ft deep, and around 30 ft in diameter, and fish were always close to the HDPE tank bottom, with the accumulation of feces, other particulates and biofouling. The tanks were heavily shaded in 90% shadecloth, to reduce macroalgal growth. Fish were therefore removed from natural lighting, as well as natural current and tidal movements. Although incoming water was not filtered at Kona Blue (as we were testing a pilot-scale system of the offshore operation, and wanted to experience the natural pests and pathogens on our fish), in most closed-containment systems the water is filtered to levels below 10 um, further removing the fish from the natural environment. The centripetal movement of the water (to aid in removal of solids) also restricted the ability of the fish to move throughout the tank; usually the fish held in place in one position, oriented into the circular current motion.

<u>2. Effluent fate and nutrient recycling</u>

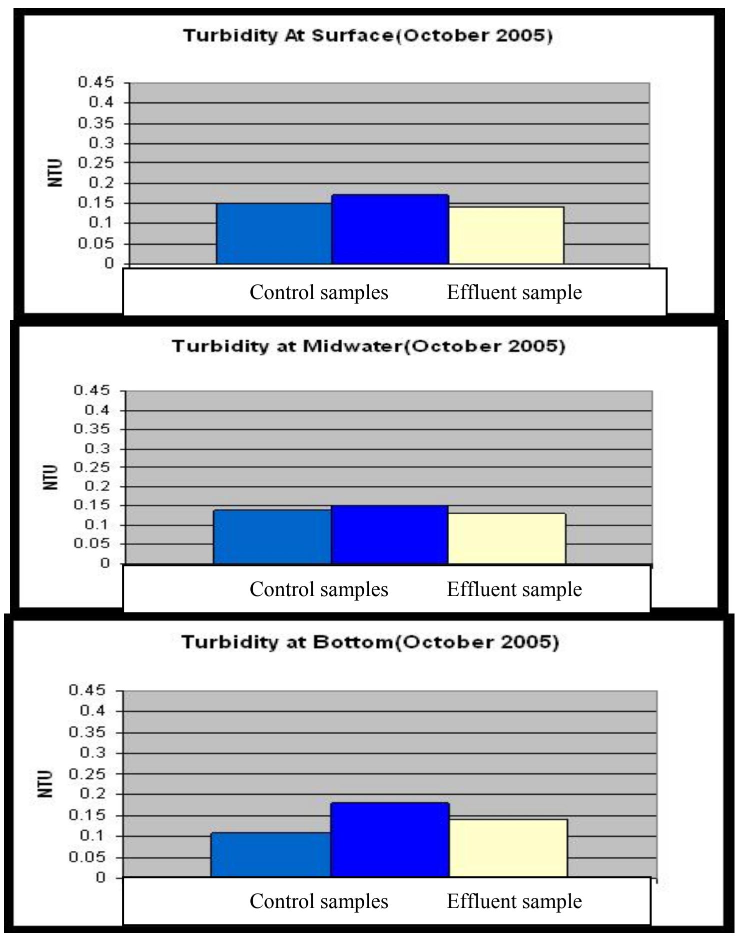
Effluent from the land-based tanks was disposed of in dispersion wells, which fed by gravity into the nearshore groundwater system. Close to the shoreline, the groundwater system in Kona is highly influenced by tidal movement, as the basalt (lava) is deeply fractured with cracks and lava tubes. Ongoing water quality monitoring by NELHA (both groundwater well points and nearshore water quality), as part of their NPDES permit, showed no measurable impact from fish farm effluent in the area. The only notable impact from aquaculture within the NELHA region is rare and anecdotal – spikes in phosphorus or nitrogen in groundwater have usually been attributable to leaks in the pond linings from one of the microalgal production companies, and are always quickly remedied upon detection.

The ultimate fate of the saltwater effluent in the groundwater is difficult to determine. Past studies with fluoroscein dye markers have shown no detectable plume of groundwater in the nearshore waters, where some traces could have been expected (Thomas Daniels, Ph.D., pers. comm.). Presumably the fully-saline effluent water sinks below the more brackish water in the upper layers of the groundwater, and dissipates into deeper water seepages at the coastline, where it then mixes with the waters of the longshore currents.

Nutrient and particulate concentration in the land-based system effluent is, purely by function of the higher biological loading in the tanks, some 1,600 times more concentrated than that from the offshore net pens. At some hypothetically greater production level, this effluent may begin to stimulate primary productivity in the immediate waters on or around the coral reef along the coastline. These nutrient-rich plumes could result in deleterious impacts to the coral reef, as increased growth of algae or filter feeders could outcompete the slower-growing corals. Even at much higher scales of production, however, such as that for the former Ocean Farms of Hawaii land-based Atlantic salmon farm at NELHA (which operated four 4 acre ponds from 1989 to 1992), no such increase in macrolagal growth along the shoreline has been detected.

Figure 2: Typical turbidity data from independent monitoring around the Kona Blue net pens.

Control samples (blue bars; up current of the farm site) consistently show no discernible difference in critical water quality parameters, such as turbidity (NTUs), from the Effluent sample (white bars; immediately down current of the net pen with the greatest biomass one hour after feeding). These results affirm that there are negligible impacts on water quality around open ocean net pens, if sited correctly and appropriately stocked. More data available at www.kona-kampachi.com.



Effluent from the open ocean net pens of the Kona Blue site is independently monitored on a monthly basis for turbidity and ammonia, and quarterly for a suite of other nutrient parameters, under our existing NPDES permit. Data from this water quality monitoring is made available both at a local repository (the State Division of Aquatic Resources office at Honokohau Harbor), and on Kona Blue's website (www.konakampachi.com). These data demonstrate that there is no measurable impact on effluent water quality, even at the sampling site immediately downcurrent of the net pen containing the greatest biomass, one hour after feeding (Figure 2).

For any significantly greater expansion of the open ocean operation, the net pens would be arrayed in a pattern across the current, such that effluents were not additive. This would mean that a broader body of water might be exposed to the effluent from the farm, but that the nutrient and particulate levels would remain insignificant, and there would be no negative impact on the ecosystem. It has often been suggested that larger scale closed-containment systems could offer the benefit of being able to filter the effluent water from the farm, to remove particulates. There has not yet been any suggestion how such filtrates might be used or recycled. The nutrients may be potentially valuable, but they would also be salt-laden, rendering them unsuitable for most terrestrial agricultural uses.

3. Energy usage and carbon footprint differential

The major energy input into the land-based tank culture of Kona Kampachi® is in the pumping of the water. The water at NELHA is pumped by the State agency itself, on a common reticulation system that moves around 100,000 gallons per minute total. This provides for economies of scale, similar to a larger commercial farm operation (as pumps grow more efficient as they get bigger, and larger-diameter pipes offer less friction loss). No additional booster pumps were needed at the Kona Blue site, since the fish in the tanks were raised with unfiltered raw seawater. The top of the tank water surface in Kona was around 15 ft (5 m) above sea level. In a floating closed-containment system, there would be no head for pumping water to a higher level. If pathogens or parasites required some greater level of water treatment, however, additional booster pumps would be needed to move the water through the sand filters and cartridge filters to remove the cysts, eggs or other disease vectors. This head-pressure would probably be around the same as the Kona Blue tank head height.

Pumps at NELHA are all powered by electricity, which is in turn generated by diesel generators. (Although the Big Island of Hawaii offers tremendous geothermal power resources, these lie largely untapped because of environmental concerns.) There is also some potential, in the long term, for Ocean Thermal Energy Conversion (OTEC) plants to pump the water and produce excess electricity, but this also brings environmental concerns: the need for disposal of large amounts of nutrient-rich, cold, low pH, CO_2-laden seawater in the nearshore environment shared with a coral reef. The major energy input for the offshore net pen system is the boat power required to move feed and farm workers out to the farm site, and to bring farmworkers and harvested product back to shore. The energy inputs and equivalent carbon burden of the offshore and the land-based culture systems are presented below, in Table 2.

This analysis, and the subsequent discussion, presumes that all other inputs to farm operations – such as shipping feed from the factory, chilling and packing fish, or shipping fish to market – are all equal for both land-based and open ocean net pens.

Table 2 : Carbon footprint calculation for land-based tank system and open ocean net pens.

(a) Electricity and carbon required to pump water to the land-based tanks

	LAND-BASED TANKS
Pump head (lift, in m)	5
Pump volume (L/hr)	6,250
Pump draw (Kw.hrs/Kgals)	0.42
Electricity demand (Kw.hrs/day)	64
CO_2 Production by electricity generation (lbs / Kw.hr)	0.55 (Note 1)
Annual carbon footprint (Tonnes CO_2 /yr)	5.7
Annual production capacity (Kg/yr)	10,000
Kona Kampachi® produced per Tonne CO_2 (Kg)	1,743

(b) Diesel and carbon required to provide vessel power open ocean net pens

	OPEN OCEAN NET PENS
Distance from harbor to site (km)	8
Average vessel round trips (No. per day)	2.5
Average time per round trip (Hrs)	1.5
Average vessel power (Hp)	500
Diesel consumption (Gallons/day)	50
CO_2 Production by diesel engines (lbs / Kw.hr)	22.4 (Note 1)
Annual carbon footprint (Tonnes CO_2 /yr)	200
Annual production capacity (Kg/yr)	720,000
Kona Kampachi® produced per Tonne CO_2 (Kg)	3,586

Note 1: Source: Redefining Progress, 2007

The offshore operation is therefore about twice as efficient, per Kg of product, as the land-based operation, in terms of energy use and carbon inputs.

In addition, the land-based production system required constant supplementation of oxygen, through a dissolved oxygen monitoring system connected to regulators and a bank of liquid oxygen tanks. Oxygen was automatically dispensed through diffuser stones in the tanks any time that the concentration fell below 6.2 mg O_2/L. The 8 tanks at full production consumed, on average one liquid oxygen VGL tank per week, or around 4,500 cubic feet O_2 (127,440 L). This equates to 662 L O_2 per Kg of Kona Kampachi® produced in the land-based system. In the offshore system, oxygen levels are always close to 100% saturation, and no supplemental oxygen is normally provided.

4. Other considerations: animal welfare and ecosystem impacts

The most notable animal welfare concern with the land-based system was the occasional failure of pumps, electricity or oxygen delivery systems that resulted in catastrophic mortality events due to asphyxia. At maximum density, there was less than half an hour from when water or oxygen would fail until fish began to die. On several occasions, complete failure of the pumps or oxygen resulted in death of all the fish in one or more tanks.

Animal welfare and ecosystem concerns offshore focus on pests and parasites and potential impact of escapes. Although sea lice proliferation and transfer from farmed salmon to wild salmon is cited as a major objection to open net pens, such effects are probably highly specific to sites and species cultured, and are probably greatly affected by different farm management strategies. There is no evidence to date of any negative pest or parasite interaction between farmed and wild fish at the Kona Blue operation. As with most *Seriola* species, *S. rivoliana* is subject to ectoparasite infections by monogenetic trematodes such as skin flukes and gill flukes (*Neobenedenia* sp, and *Zeuxapta* sp, respectively). Ongoing monitoring of wild fish in the area around Kona Blue's farm for parasite prevalence is being conducted to determine if there are any proliferative impacts on the wild stocks. This monitoring shows that *Caligus*-like copepod parasites are highly prevalent in wild *Seriola rivoliana*, at an average of around 12 individuals per wild fish. However, there have been no instances of such parasites being found among farmed stocks to date. Furthermore, wild *S. rivoliana* have negligible levels of *Neobenedenia* sp (around 0.22 individual flukes per fish), and no *Zeuxapta* sp. Wild *S. rivoliana* are also heavily laden with internal parasites – both intramuscular and gastro-intestinal worms – to the point where commercial or recreational fishermen rarely keep any of the wild *S. rivoliana* that they catch. No such internal parasites have been found in cultured Kona Kampachi®.

Sea lice control measures are also sometimes cited as problematic, with residual chemicals reportedly found in the surrounding environment. The integrated pest management strategy employed by Kona Blue to control parasites in the farm stock, however, adheres to the Organic aquaculture standards already recommended by the NOSB for approval by USDA.

Because of concern over potential escape impacts, Kona Blue's operation does not presently use any broodstock beyond F2 generation (i.e. second generation of captive bred fish), and there is no conscious selective breeding in the hatchery. Given that open ocean aquaculture continues to push the engineering envelope, some periodic catastrophic escapes could be expected over these development years. The key is to minimize the potential ecological impacts of these escapes. This can best be managed in open ocean systems by limiting Organic production to native stocks, or introduced species that are well-established in an area. The degree of selective breeding is of concern with fish that are naturally scarce, or have been rendered so by commercial fishing pressure. In such situations, a significant escape event of selectively bred fish could result in some skewing of the wild gene pool. Some regulation of the genetic differences between wild and farmed stocks is appropriate where escapes could be expected to result in such impacts.

Many anti-aquaculture activists point to the migratory nature of salmon as antithetical to Organic principles. However, such objections might also be equally applied to cattle, ducks and geese, whose wild counterparts were also migratory. Most marine fish that have been held under culture appear to suffer no ill-effects from being restrained from following innate migratory urges. Within several generations, such instincts could be expected to fade.

The problems of predator management in salmon farming are also often cited as reason for excluding net pens from Organic standards. However, predator management is a critical part of all livestock farming. Resistance to predator attack is one of the primary attributes of net pens such as the Sea Station™ and the Aquapod™, which are designed for open ocean situations. There is only a single instance in Kona Blue's two and half years of operation offshore where a predator has caused a breach in a Sea Station net (a shark bite in an area of net that was not tensioned correctly). No predator controls or deterrents are currently used at the Kona Blue offshore farm site. Organic standards should foster humane, rational predator control methods that do not have a detrimental impact on the predator's role in the surrounding ecosystem.

DISCUSSION

This comparison of the two systems suggests that the biological loading, and therefore the physiological stressors on the fish, are far greater in the land-based tank system than in the offshore net pens. As well as the biological loading being 1,600 times greater in the land-based tanks, the density of fish is another 67% greater than in the offshore net pens.

While neither the land-based system nor the open ocean net pen system has any measurable or scalable impact on water quality, the potential impacts for some larger expansion can be imagined. If additional open ocean net pens are sited strategically perpendicular to the direction of the prevailing currents, the additional biomass from this expansion would not result in any cumulative (additive) impact on water quality. However, expansion of land-based fish farms, either further away from the coastline or further along the coast, could result in additive impacts from increased concentration of farm particulates and dissolved nutrients in the groundwater. Anecdotal evidence suggests that major alterations to groundwater nutrient loadings along the Kona coast from non-point sources, such as from golf courses or other effluent inputs, does indeed result in degradation of the nearshore coral reef ecosystem.

Recent modeling work also suggests that the ecosystem impacts from an offshore fish farm can actually be beneficial – so long as the farm is carefully sited and appropriately scaled (Rensel and Forster, 2007). In waters where hydrodynamics are such that the particulate matter and dissolved nutrients are retained within the mixed zone (the upper 50 – 100 m of the water column), then these inputs are rapidly assimilated. In oligotrophic (nutrient poor) ocean waters (i.e. most tropical ocean waters, except areas of upwelling, such as off the western coasts of South America or Africa), then these inputs form the basis for a trophic pyramid; essentially the farm becomes a productivity pump, with microalgal primary producers taking up the nutrients, planktonic filter feeders and other herbivores grazing on the microalgae, and carnivorous plankton or fishes forming several subsequent trophic levels. This modeling is site-specific, depending on the amount of inputs and the degree of mixing (currents, winds, water depth, etc), but the fundamentals remain the same (Yngvar Olsen, unpub. data).

Other recent studies have shown that even if particulates do fall to the substrate, that periodic strong current events can dissipate the organic material, and prevent any accumulation and subsequent anoxia (Rensel and Forster, 2007). Some ecosystem perturbance may occur in the area immediately around the farm, as species that are more tolerant of nutrient-rich conditions begin to dominate. These impacts are compensated for by increased productivity and biodiversity in far-field effects (ibid). Recovery from these disturbances is usually rapid – on the order of one to two years from when the fish are removed before benthic ecosystems are returned to pre-existing conditions.

Environmental impacts from fish farm effluents are usually only problematic where farms are located in more enclosed or shallower bodies of water, where there is little mixing in the upper water column, where currents are slow, or where the net pens are close to the substrate. In these situations, nutrient inputs can become cumulative, or particulates can settle to the seafloor, with resulting deterioration of the benthic habitat. An analogy to terrestrial agriculture may be useful: the wastes from livestock ranched in pasture are usually assimilated and recycled into primary production. In infertile soils or the lined pens of feed lots, however, livestock wastes will accumulate, and are not recycled by the local ecosystem; the wastes then become problematic. The key, therefore, is to site Organic terrestrial farms in appropriate locations, with soil types and animal densities that are adequate for assimilation and recycling of wastes. The same principles should apply to Organic net pen culture.

The water quality data presented here provides further affirmation of the environmental compatibility of open ocean net pen culture systems. If sited correctly, open ocean aquaculture has no significant impacts on water quality or benthic substrate. Organic standards should therefore address specific siting requirements, such as depth of water, currents, the enclosed nature of the body of water, other hydrodynamic influences, and potentially sensitive or limiting factors downcurrent. There should therefore be no compulsion to fallow offshore farm sites, but again, site-specific evaluations must be made.

The evidence from wild stock monitoring of *S. rivoliana* suggests that net pen culture does not invariably have negative impacts on wild stocks. For Kona Kampachi® grown in well-flushed offshore sites, there is no significant pest or parasite interaction between wild and cultured stocks. Again, if it is only some species and some sites, that are of concern, then Organic standards should differentiate between those that are acceptable, and those that require some more careful siting, or more rigorous monitoring and treatment of pest and parasites

Those who are gravely and genuinely concerned with the potential environmental depredations of salmon farming should perhaps consider a hypothetical open ocean salmon farm, located, say, in the center of the Atlantic Ocean. If the impacts of this farm can be considered negligible, then might it not be considered as a candidate for Organic status? Or is it, by its very nature as a salmon farm, excluded from such consideration? If so, then on what basis? Simply because it is a salmon farm? If this is the rationale that is to be applied, then we should be explicit: perhaps it is indeed just salmon net pen farming that offends. This then avoids the unfortunate 'collateral damage' of the potential exclusion of all other fish in net pens from Organic farming, simply because of other biases or bigotries. And if this salmon farm, with negligible environmental impacts could be accepted as Organic in the mid-Atlantic, can it not be gradually moved closer to shore, into shallower waters? Then at what point, and using what criteria do you begin to judge it incompatible with Organic standards? By applying this thinking, we can see that net pens can and indeed should be allowed to be Organic. This assertion by no means diminishes the need for adequate standards to be established to ensure that such operations adhere to Organic principles.

To address the NOSB's specific questions on these issues, then:

1. <u>How can open cage net pens be ecologically responsible? What requirements need to be included in the proposed regulation to assure this? How can the issues of water flow and rotational locations be included? What are the other issues?</u>

There are three factors that primarily affect the ecological responsibility of open net pens: the species cultured, the biomass, and the site. The overarching aspiration of Organic net pens should be to operate with minimal impact on the ecosystem. Therefore culture of non-native or GMO species should be proscribed. The biomass within any one facility should be such that wastes can be readily assimilated by the surrounding ecosystem, or dissipated into the wider ecosystem. Siting considerations (a range of interrelated variables, including water depth, current velocities, and other hydrodynamic mixing) are difficult to integrate or prescribe. The governing principle should be care for the surrounding ecosystem, and the burden of proof should be on the farmer to demonstrate that the operation is within sound ecological guidelines.

Rotational fallowing of farm sites is not appropriate for open ocean net pens, where the incentive should be to site farms in deeper water, with stronger currents, to create a disconnection between the farm's nutrient inputs and the benthos. Insistence on fallowing practices would double mooring costs, due to redundant anchoring systems; such investments would be best expended on anchoring the facility in deeper, faster flowing waters. Incentives should be established for farms to move deeper, not into shallower water.

2. <u>Sea-lice: What is the prevalence or rate of sea lice infestation in wild fish populations where there are no net pens? What are the regional variations? Are sea lice infestations inherent with open cage net pen systems? How can they be controlled without prohibited substances in an organic system?</u>

The AWG's recommended language that "Facility managers shall take all practicable measures to prevent transmission of diseases and parasites between cultured and wild aquatic animals." (§205.255 (k)) is appropriate. Language such as "Monitoring shall be employed to ensure that wild conspecifics or other wild fish are not subject to harmful disease or parasite burdens originating from proliferation within the facility" would provide some assurance of wider ecosystem protection. Parasite control questions should again not be prescriptive. The desirable goals for Organic farm management should be established, and farmers should be encouraged to strive to attain these goals using innovation and astute farm management.

3. <u>Escape: What is the current rate of escape in the conventional aquaculture and the developing organic aquaculture industry? How can the issue of escape be better controlled in an organic system than in a conventional ocean-based system? Are there any implications to containment farming of fish species not indigenous to that geographic area other than cross-breeding with native species?</u>

Escape rates will presumably be higher as facilities – in an effort to reduce impacts on benthic ecosystems - move towards more exposed sites. Escapes can also be expected from open ocean net pen technologies as they are tested at commercial scales. But escapes *per se* are not the problem; otherwise, the anti-aquaculture activists would similarly object to the massive hatchery-driven stock enhancement efforts for salmon in Alaska and British Columbia. The problem is where escapes have a detrimental impact on the wild ecosystem. This is manifested either by direct impact (competition with wild fish for food or space) or by genetic dilution of wild conspecifics. The former is not a significant long-term problem (particularly given the past depredations on stocks from commercial fishing, and consequent genetic skewing of wild gene pools). The latter, however, could be a concern. Organic standards should address this risk by restricting selective breeding, within the context of the escape record of the farm, and the status of the wild stocks. Unless there is some assurance of minimal impact, then some conservative level of selective breeding should be established (say, F2) for Organic culture.

4. <u>Assimilation of waste: How much can any system expect to mitigate waste in outflow and settling of waste in open pen systems? Actual data regarding the inflow and outflow of nutrients of existing operations claiming sustainable practices would be the most helpful.</u>

The AWG's recommendations that "Aquaculture facilities shall be designed and operated to minimize the release of nutrients and wastes into the environment." should be recast for net pens, to rather "Aquaculture facilities shall be designed and operated to minimize the release of, or – in the case of open net pen culture - optimize the assimilation of nutrients and wastes into the environment."

The AWG's recommended language that "Metabolic products of one species are recognized as organic resources for one or more other species in an aquaculture production system" should be broadened to accommodate the wider dispersal of nutrients in aquatic environments. Language such as " … organic resources for one or more other species in an aquaculture production system or in the wider aquatic ecosystem." would be more appropriate.

The AWG's recommended language that "Open water net-pens and enclosures are permitted where water depth, current velocities and direction, stocking densities, and other factors act to adequately disperse metabolic products in order to minimize accumulation of discharged solids on the bottom sediments under the net pens. … Monitoring shall be employed to ensure that the natural assimilative capacity at the site is not overburdened." (§205.255 (k)) is most appropriate, and laudable.

There appears to be adequate guidance for assimilative boundaries in the requirement stipulated in §205.255 (f): "The rate of effluent discharge must not exceed the natural assimilative capacity of an area within 25 meters of the site boundary nor contribute significantly to environmental degradation beyond 25 meters of the site boundary."

The AWG's recommendation that "Use of multiple species of aquatic plants and animals to recycle nutrients must be included in every management plan" in §205.255 (k) is not appropriate for more exposed open ocean facilities. Insistence on recapture of nutrients by the facility provides a clear disincentive to site farms in more exposed waters. Instead, farms should be encouraged to locate in sites exposed to stronger currents, where nutrient recycling can be accomplished through the broader ecosystem functions. In exposed sites, a farm strives to minimize drag on the moorings by reducing the surface area exposed to the current. Secondary culture of bivalves or macroalgae will instead add to drag, increasing the risk of mooring failure; reducing water exchange through the net pen; or providing a reservoir for pests or parasites.

5. Predators: What is the risk to and from predators in open pen systems? In relation to language in the AWG document, in what ways is the section on predators adequate, or in need of changing, etc?

The taut mesh on open ocean net pens renders them largely immune to predator attack, and harbors little risk of entanglement to the predators. There may be instances where lethal force is necessary to ensure worker safety, but these should be very rare. Generally, the AWG language is adequate, and appropriate.

6. Migratory issues: How is migration a valid issue for these fish at the stage of life when they would be housed in open net pen systems? If so, what are these issues and their implications?

Migration is not an issue for domesticated cattle, ducks, or geese; nor should it be an issue for domesticated fish. It is difficult to imagine that animals that are several generations removed from the wild, having been reared in the hatchery and raised in tanks or net pens their entire lives, still maintain such strong migratory urges that it becomes an animal welfare concern. Rather than a residual instinct in cultured fish, this is, more likely, a residual emotional attachment of the anti-salmon farming activists to their iconic fish.

CONCLUSIONS

Based on Kona Blue's experience with culturing Kona Kampachi®, it appears that closed-containment systems are further from the ideals of Organic aquaculture than adequately sited open net pens. Closed-containment could be rendered safer for the fish and less physiologically stressful by lowering the culture densities in the tanks. Lower densities would also reduce the nutrient and particulate load on tank effluents. However, lower fish densities in capital-intensive tanks would also be less profitable. The economic viability of large-scale closed-containment systems is already under question - simply by the dearth of definitive examples of profitable closed-containment farms - and becomes increasingly tenuous with rising energy costs. It is not clear if consumers would be willing to pay the premium for closed-containment-reared fish. Perhaps the best validation of commercial viability of such systems would be a flurry of tank farms becoming established out of entrepreneurial opportunity, rather than on the backs of government fiat.

Closed-containment systems could still be considered Organic, so long as the same standards of animal health and welfare are applied as for recirculating systems. (e.g. §205.255 (n) should be modified to read “Recirculating systems or other high-density containment systems are permitted if the system supports the health, growth, and well-being of the species …”). But these systems should clearly not be seen as a preferable Organic alternative to appropriately sited net pen farms.

Compared with our land-based tanks, Kona Blue’s offshore operation holds the fish at lower densities, with significantly lower biological loadings on effluent, and less burden on other natural resources such as energy. Further, the nutrients and particulates from Kona Blue’s net pens have no measurable impact on effluent waters. Modeling suggests that appropriately sited fish farms become centers of productivity in otherwise oligotrophic ocean waters, and these nutrients are therefore recycled through the broader ecosystem functions, rather than within the boundaries of the farm itself. This still appears to adhere to the fundamental Organic principle; it is just a question of a different scale than that of terrestrial agriculture.

Open ocean culture might therefore be considered an ideal fish production system, in terms of minimizing environmental detriments, and promoting biodiversity and productivity in otherwise depauperate waters. There is no good reason why such systems should not be considered Organic. The question then is not whether net pen culture should be allowable as an Organic system, but rather, what other standards need to be established for marine net pen systems in nearshore waters to comply with Organic principles. The key element, as expounded here, is siting. The Organic standards should therefore contain criteria that ensure that these broader assimilative ecosystem functions are supported, and that accumulative impacts on the immediate waters, benthos or biological community are not significant.

Establishing Organic standards for net pen culture systems should also have wider health benefits, by reversing the unjustified, immorally-based, consumer-aversion to most farmed seafood, and encouraging stronger consumer confidence in farmed fish, and all seafood. This should then increase overall seafood consumption, resulting in better overall health, less heart disease, and reduced mortality rates (Mozzaffarian and Rimm, 2006). To deny the opportunity for Organic status to net pen culture is to condemn the oceans and consumers to a lower standard of farmed seafood production, or none at all. That would be neither good for the fish, good for the oceans, nor good for humanity.

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