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Closed–containment aquaculture in Atlantic Canada

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Abstract

This paper explores the development of a new type of aquaculture which is beginning to occupy a modest economic niche in contemporary food production. Just as open-cage production attracted considerable social science attention in the 1990s, closed-containment production is now being evaluated as a preferred alternative. Close-containment has been viewed as an approach which may, to some degree, address problems associated with the first wave of industrial aquaculture: disease, genetic modification, food waste and social externalities. As with the first wave of aquaculture development, the financial demands and energy requirements of this new system have restricted development to species which are suited to the new technologies, and command high enough market prices to justify their growth. Using information collected at four major, but different sites in Nova Scotia, this paper attempts to provide some initial comparative insights on an important new trend in contemporary aquaculture.

Introduction

The primary aim of this essay is to introduce a second generation of aquaculture experiments designed to evade some of the environmental problems which have emerged with the expansion and production successes of first-generation, open pen aquaculture. We will simultaneously explore some theoretical frames which may be valuable for understanding and explaining the new aquaculture projects. Thirdly, we will create an historical record of some of the early ventures in the field, as experience with the first generation suggests a number of these enterprises will shift organizational forms, or disappear altogether. Whether the increasing sociotechnical demands of closed containment aquaculture offer a contested path to another niche in the post-industrial economy is the key question which motivates this exploration.

The first major social science exploration of open pen aquaculture is only a decade and a half old (Bailey et al. 1996). Although initial production efforts predate this interest by 25 years, their origins as variants on traditional rural-based capture fisheries meant a slow upward development trajectory, and a significant time lapse before corporate industrial interests began to move into feed and fish production, as well as marketing. However, the absorption of open pen aquaculture into global production and marketing chains has, for better and worse, pushed the industry into a major position in world fish production. This transition has, as with other major food production systems, meant the end of small-scale and/or social democratic hopes for a more egalitarian, democratic economic base for community existence.

The new experiments with closed containment aquaculture, motivated in part by an attempt to address the new environmental challenges, raise questions about the extent to which closed containment production may represent another halting step towards a post-industrial future. The progressive interpretations of post-industrialism, which began in the early 1980s (Piore and Sabel 1984), emphasized the combination of small-scale economic activity, along with innovative productive techniques which could capture niche markets. For Piore and Sabel, the northern Italian textile plants were a prototype, but the prospects were broader, but also historically contingent. The post-industrial fisheries prospects, in both capture fisheries, and aquaculture, have been historically-specific, with the social struggle for new, innovative forms of development running into various obstacles thrown up by the neoliberal waves in North America and western Europe since the 1980s. In terms of capture fisheries, Nova Scotia had an opening created by the declaration of a 200-mile limit in 1977, a boundary within which small-scale fisheries of various sorts initially believed they had opportunities which came with federal government backing (Apostle and Barrett 1992). However, a decided North American shift in a neo-liberal direction swamped the variegated small producers in a surge of nationally-based corporate activity. In overly simple terms, the large-scale foreign fleets which had been stripping Atlantic fisheries were replaced by domestic corporations dedicated to the same ends. The collapse of the North Atlantic cod stock was one of the many negative byproducts of this Atlantic Canadian era of corporate greed. In terms of aquaculture as post-industrial activity, the Faroese government experiment of the 1980s with salmon farming was perhaps the clearest attempt in the industrial north to create a new economic system, based on small enterprises located in the many smaller communities scattered around the archipelago. The wave of infectious salmon anemia (ISA) which wiped out a considerable number of enterprises located in the slow-moving waters between the two main islands, as well as a drift to the economic and political right, led to a round of economic concentration that ended any progressive prospects (Apostle et al. 2002).

To the extent that environmental challenges represent the thorniest, and most important, challenges to a new century (Held and McGrew 2002: 128–129), endeavours which move us towards innovative solutions do contribute to the construction of a new order. However, like other economic initiatives, closed containment aquaculture is typically caught up in the use of some existing technology, if only to capture the use of abandoned industrial sites and resources. Further, the financial requirements of new productive systems sometimes involve painful negotiations and obligations to a traditional banking system, as well as the requirement to market products as small actors in a transnational marketplace. Finally, like other small businesses, there is a strong incentive structure for aquaculture to locate in (rural) areas which can provide a relatively cheap labour force and/or buffered living costs.

The other theoretical requirement for this new domain is a satisfactory approach to understanding scientific activities. At first glance, the relatively advanced technologies required for this type of aquaculture may appear to be adequately interpreted by standard science and technology assumptions (Shapin 1995). However, the fact we are dealing with marine resources which are only partially dependent on terrestrial activities does raise questions about the micro-social tenability of these assumptions. The marine world, with all the uncertainty implied by dependence on species which do not have the same immediate visibility, raises the prospect that any new post-industrial theoretical approaches will need to be complemented by some variant of actor-network theory (Apostle 2009). The social sciences have a long tradition of adopting investigatory assumptions which parallel the natural sciences, stretching from Merton (1968) to Shapin (1995). The emergence of environmental issues, and associated problems, from the 1980s forward, have stimulated the emergence of new perspectives, ranging from radical ecological positions (Naess 1989) to various intermediate theories which postulate the basic equivalence of natural and social phenomena in defining new social science approaches.

These latter “equivalence” viewpoints, most popularly captured in actor-network theory (Latour 2005), see natural phenomena as “actants” having roles in networks equivalent to human actors. These theories range from the more constructivist side of the spectrum (Finlayson 1994), to more realist positions (Law 1986). In their more extreme formulations, fishers and scientific officials, may at least temporarily be understood as part of a “constraining network of relationships”, along with marine species, like scallops (Callon 1986). While one may reasonably question the anthropomorphizing tendencies in these analyses, and the neglect of large-scale social structures, there are definite prospects in some of the modified formulations (Haraway 2003) for a new approach to marine affairs which reasonably complements more traditional approaches. Briefly, non-humans, in Haraway’s work, do have actor status, but it is asymmetric, with humans retaining a location at the center of natureculture.

Another useful variant on actor-network has been introduced in a recent issue of MAST (7:2). At a general level, the journal issue introduces the notion of cybernetic organizations, or organizations which are “complex heterogeneous associations of humans, fish and technologies of control and environment” (p. 5). The most intriguing extension of this notion occurs in an article by Johnsen et al. (2009b). The authors view cybernetic organizations as a logical shift from the preceding “mechanical” social order, with a closer connection between humans, machines and fish, but a connection which still preserves an asymmetric primacy for human actors. These new networks also acknowledge the presence of power relations, even if they are less centralized than predecessors from the mechanical era. Other MAST articles postulate the creation of “formalized cybernetic relations” (Johnsen et al. (2009a), p. 12) and the emergence of “an extreme interface between human and machine”, with an increasing technical primacy in commercial fisheries operations, with fishermen and –women unable to substitute for machinery and systems, “but machinery and systems can replace people” (Ibid., p. 24).

With these two complementary theoretical frames, one drawn from the macro-world of post-industrialism, and the other from the micro-world of actor-network theory, we now turn to four examples of closed containment aquaculture, with each representing more “closed” aquaculture production. Information for these cases was gathered using standard fieldwork procedures, involving both qualitative interviews and field observation. Specifically, this study is based on visits to six different aquaculture sites, or establishments, across Nova Scotia, and 12 semi-structured interviews with key personnel at these sites (one interview, for the convenience of the interviewee, was conducted in Halifax). These aquaculture sites, like traditional capture fishing enterprises, are located in rural areas, all quite distant from the Halifax urban center of the province. The shortest distance travelled on a given foray was approximately 161 km. To make the fieldwork challenge more interesting, the individuals to be interviewed are all active members of the industry, with little time to spare. This meant that interviews and/or visits were not infrequently rescheduled. At the extreme, the investigator had to patiently wait a year and a half to complete the work. It should be acknowledged that once direct contact was made, the individuals involved, like their more traditional counterparts in the capture fisheries, were generous both with time and information.

The investigator also attended the 2010 Aquaculture Association of Nova Scotia (AANS) annual meeting. The AANS President at that time was the founding figure for closed containment aquaculture in the province. And, given that aquaculture of any sort is a relatively marginal economic activity in Nova Scotia, the meeting was unusual for the degree of cooperative engagement. By contrast, personal attendance over a number of decades at capture fishery industrial meetings was rarely marked by this type of collegiality. This contrast may diminish as the new sector grows.

Closed containment

Closed containment, in one widely-circulated Canadian report, is defined as "Any system of fish production that creates a controlled interface between the culture (fish) and the natural environment" (Ecoplan International, 2007, p.2). A number of benefits are frequently associated with closed containment production. These variously include avoidance of the following open-cage problems: the spread of major parasites or diseases (sea lice, ISA); undesirable genetic transformations due to escapes of caged fish; and food waste which falls through open cages, and the associated buildup of "ammonia, nitrates, phosphates, organics (creating high biological oxygen demand)" (Ecoplan International 2007, p. 55). The deposit of fecal matter as sludge beneath the open cages is an associated difficulty. At an economic level, there is the question of "externalities", or the costs of production which are borne by third parties. This issue is sharpest where open-cage aquaculture is conducted in areas of high human population density, and in proximity to valuable wild stocks. In this regard, it is no surprise that the British Columbia coastline, across to Vancouver Island, is a flashpoint for conflict between traditional aquaculture and environmentalists (many of whom advocate closed containment as an alternative). By contrast, small, isolated archipelagoes, like the Faroes, which can more easily dispose of aquaculture wastes, and are strongly committed, as a society, to a fishing tradition, have considerably fewer concerns about externalities.

There are some basic points about closed containment systems which need to be made at the outset. First, one needs to distinguish between salt water and fresh water systems. The basic technological structure and demands are quite different. The salt water variants include rigid wall and flexible wall construction; fresh water technologies include flow-through and reuse alternatives (there are also salt water reuse technologies). The variety of closed containment schemes, which go well beyond the major variables enumerated here, bespeak the uncertainty which characterizes a new area of scientific endeavour. The primary goal is the search for commercially-viable ways to raise various fish species, and the failures to date vastly outnumber the few (partial) successes (Fisheries and Oceans Canada 2008).

Whether salt water or fresh water operations, these technologies are usually regarded as more environmentally-friendly, because it is much easier to control major problems, like sea lice, and ISA (Intrafish 2007). Closed containment is also viewed as "reducing escapes, contain wastes, and eliminate interaction between farmed and wild fish and marine mammals. . ." (Intrafish, August 6, 2007).

Second, the economics of these systems are currently quite demanding. In particular, energy costs mean that these systems can only be used when the species or age-groups being reared are decidedly profitable. If one can sell halibut at CAD$16 per 0.5 kg, char at CAD$12 per 0.5 kg, or 60 g salmon smolts at CAD$2.60 each, one may be able to undertake profitable production. Lower prices will not support sustainable production. More specifically, efforts to establish commercial closed containment salmon sites have frequently failed. And, since aquaculture is a decidedly opportunistic, new industry in the advanced political economies, especially in liberal capitalist ones, people will move quickly to abandon (or follow) new production systems.

Third, one has to find supportive physical and social environments to undertake closed containment aquaculture. Due to the search for cheap labour, one is usually talking about rural areas, as well as ones that are possibly in need of economic development (Apostle et al. 2002). In Nova Scotia, it is no surprise to find most of the new operations located well away from the provincial center, the Halifax-Dartmouth metropolitan area. The major sites are in the Clark's Harbour-Woods Harbour area on the South Shore, and Advocate, on Cape Chignecto, in the Bay of Fundy. Further, several sites, both successes and failures, are located on, or in conjunction with, First Nations sites.

A fourth, more theoretical set of points may be made. Closed containment production, with its immediate appeal to environmental sensibilities, and its greater prospects for easier access to environmental labeling, fits more easily into a post-industrial world-one which values sustainability in ways which were not central to the industrial era.[a] Second, the even higher capital-labour ratios of the new aquaculture speak directly to the increasingly close connection of technology and human labour, with an augmented primacy assigned to the new technologies. "Cyborgization" expands its grasp.

Not only are these closed containment sites places any provincial government would want to see developed, both for employment and economic growth, they may also hold the prospect of secure food supplies close to the local population. If, as one interviewee puts it, "transportation costs are the global leveler", then the need to find more sustainable food sources close to local markets will become more important. People will have to be more concerned about their "one hundred mile diet". Again, such development can only proceed in the context of global food markets. Local aquaculture products only become desirable if they can match or surpass competitor sources for price. And the optimism, if one may call it that, is based on the knowledge that world capture fisheries have peaked in terms of their production; any future gains have to come from some form of aquaculture. Further, closed containment aquaculture, at least in the industrial world, is a recent innovation, with the thirty (or more) year history one associates with an industry in the making.

Finally, one must appreciate the extent to which a debate which has initially been formulated in economic and technological terms has social fundaments (Schreiber et al. 2003). If they hope to be persuasive in the public domain, environmentalists and fish farmers, even as sometime adversaries, are forced to share a common language generated by reigning social values. Thus, terms like "productivity", "efficiency" and "technology" may acquire subtle, and not so subtle, differences in competing interpretative frameworks, but they remain the core concepts around which the initial debates revolve. It is the very complexity of these debates which attests to their basic social character (Schreiber et al. 2003).

Closed containment in a world of open systems: case 1

One alternative to technologically-imposed interfaces is the use of open bodies of water which may, due to their location and composition, serve as functional equivalents of a "controlled interface". In the Bras d'Or Lakes of Cape Breton, oyster production has been successfully pursued in a number of locations over a considerable period of time. In the period following the collapse of Northern cod in the 1990s, oyster leases were extended to a number of ground fishermen to augment or supplement their incomes. The industry prospered, particularly around Eskasoni, to the point that it became a CAD$1 million a year business, rivaling that in both New Brunswick and Prince Edward Island. Unfortunately, the year 2002 saw the Bras d'Or Lakes "nuked" by the parasite carrying the disease MSX. Despite the fact that the only danger the disease poses is to the oyster itself (the oyster gradually dies for lack of oxygen), and to the longevity of oysters affected by the disease (which may range from a month to a year and a half), the oysters became unmarketable.[b] Producers on the Bras d'Or Lakes have found it difficult to obtain either government or private funding to recommence oyster farming. The producers think a number of agencies are shying away from the area for fear of being associated with the propagation of the disease. Nevertheless, plans are beginning, on a small scale to resume oyster, mussel and eel farming, as well as salmon and trout farming. At Eskasoni, which was hardest-hit by MSX, plans are emerging to begin oyster farming in closed containment conditions, to provide effective quarantines. The producers would also like to combine this with salmon production in "race" boxes on streams, with the oysters and mussels cleaning up waste products. This form of mariculture would be more desirable than systems which do not filter their waste products. One factor which may push government agencies to move is their legal obligations to the First Nations groups which are at the center of inland aquaculture in Cape Breton. A number of the species involved are traditional food or ceremonial resources for the Mi'kmaq, including oysters, mussels, and eels. And, while these cultural ties may be advantages in dealing with government, they also impose internal constraints on the First Nations groups, as they move to produce new stocks. First Nations commitments to more holistic, environmental production place constraints on commercial activity. For example, while young eels (elvers) which may be very valuable commercially, the First Nations preference for seeing food through its life cycle may pose some interesting questions. A First Nations group in Whycocomagh has pushed their thinking about quarantines and closed containment one step further. They argue that some parts of the Bras d'Or system actually function effectively as closed containment areas both because some of their bays constitute "micro-systems" due to the deep basins, relatively low salt content, and the slow transfer of water with the ocean itself (approximately 600 days for one cycle). The low salt content (perhaps 50 percent) kills the MSX parasites. Water transfer is slowed by the existence of major sandbars at the mouths of the bays. For this reason, Whycocomagh Bay is referred to as a "Barrachois pool". And, despite its current difficulties, the Bras d'Or Lakes may actually benefit from "the privilege of backwardness". Large foreign and national aquaculture companies have moved into Nova Scotia, and nearby southwestern New Brunswick, with existing technologies, and the companies are finding themselves stagnating, due to the environmental problems inherent in large-scale production (many leading to the call for closed containment production). However, Nova Scotia, which may lack obvious aquaculture sites, will have to develop its own technologies and organizations. Nova Scotia aquaculture will probably be based on (spatial) specialization, and knowledge which is home-grown, not "transplanted". For their part, in Cape Breton, as one local producer put it, "the Bras d'Or may be the best hatchery in North America". The problem, one already encountered in practice, will be creating their own transport systems, ones which, given some of the distances involved, will have to involve water-change stations. But Nova Scotia has the advantage of being able to produce seed oysters earlier than their American counterparts on the eastern seaboard.

Closed containment in a world of open systems: case 2

One full-fledged representative of closed-containment aquaculture on the East Coast is land-based, saltwater recirculation technology. The longest sustained experiment in Nova Scotia, one which is only a decade old, has been successfully concentrating on raising halibut, either to juvenile or adult status, before selling them to other grow-out sites, or directly to commercial markets.[c] One major economic advantage this operation has, like many of the other closed-containment systems in Atlantic Canada, is the presence of unused fish processing buildings in which they can locate their new technologies. The closed containment operation is integrated with a hatchery located in a nearby community. The particular advantage for this site is that it is utilizing financially inexpensive buildings which were previously used as a rockweed (seaweed) plant. Another, associated advantage, one which makes the East Coast attractive, is the possibility of location in rural areas, far from any population concentrations. Not only does this largely solve the problem of NIMBY claims, it also provides access to relatively cheap rural labour, as well as the possibility that workers will be able to access good, inexpensive housing, as well as a desirable rural lifestyle some, as urban refugees, are pursuing.

By comparison with some similar West Coast alternatives, this particular complex has an advantage of generally being located close to the waterline, and having its pump house located closest to the ocean. The system brings the water through a lengthy cement runway which permits sediment to settle, and to be disposed of. The water is then both oxygenated, sterilized (by ultraviolet light) before being fed through a main head tank (and a reservoir, on return) into the grow-out tanks.

Given the sedentary nature of Atlantic halibut, the amount of make-up water which has to be introduced on a daily basis is limited to 30 percent (Blanchard et al. 2003, p. 30) by the desire to leave the fish relatively undisturbed. The first part of the system has a backup generator, one which has only been utilized during one storm over the past five or six years.

The large grow-out tanks are typically clustered in “modules” consisting of anywhere from 6 to 18 tanks. I counted approximately 68 such tanks, approximately half of which are currently in use. The tanks are primarily composites of fiberglass and plastic; some are cement. The brood stock now comes exclusively from their own hatchery, although during their startup years in the late 1990s they had supply connections to an Icelandic company. The halibut can be grown to full market size, but many are now being sold as juveniles to companies in Norway and Scotland. These European companies, in the new global twist which characterizes aquaculture, market most of their mature fish back to American markets. In addition, this particular plant has been conducting a two-year experiment with dulse and Irish moss (seaweeds) to determine their effectiveness as water filters.

The company continually experiments with different sources of feed. It has few transportation problems, as it has one truck of its own, quick access to trucks controlled by one of the owners, and general use of rental trucks. Thus, transport to other parts of Canada, the United States or Europe pose few difficulties. One striking feature of the small workforce is its relative youth. The oldest regular employee, the assistant manager, is only 24 years of age. This youthfulness has also been generally true at other sites in Nova Scotia, and speaks both to the age of the industry, and perhaps perceptions of its future.[d]

Closed containment in a world of open systems: case 3

The third type of closed containment system in the province is located near the Bay of Fundy in northern Nova Scotia. The system is described by its marketing manager as "the largest non-recirculating system in the world". It concentrates on producing salmon smolt, as well as halibut, and Arctic char. Like other closed containment systems, the establishment, given its energy requirements and infrastructure costs, has to have "very high value units" going out. This establishment is closely tied, through family connections, to another closed containment site which is inland in northern Nova Scotia. The second, original site, which predates the Bay of Fundy location by almost 20 years, currently focuses on the same three species.

The original site, the inland one, began raising trout inland in the early 1970s and grew slowly, due to the need to accumulate capital to fund the farm. However, with the end of the commercial capture fishery for salmon, the prospects for aquaculture generally in the Maritimes expanded considerably. The facility currently produce about 1 million Atlantic salmon smolt a year, and 2 million juvenile salmon, as well as 60 metric tonnes (mt) of Arctic char and 40 mt of Atlantic halibut. Much of the smolt production is currently shipped to southern Newfoundland for growout, and helps the Newfoundland salmon industry. The producer uses fish food with vegetable protein from a major European company, and is starting to produce their own zooplankton and special vegetable protein to improve omega-3 quality. Their careful practices have earned the two, linked establishments a "green" certification from the British Colombia Aquarium for the production of sustainable seafood.

The Bay of Fundy operation was begun in the late 1990s, after it had been ascertained that the operation could drill geothermal wells in the area, ones which contain both saltwater (to a depth of approximately 24 m), in addition to freshwater, separated by clay and bedrock. These wells, in conjunction with several freshwater wells, supply a system of on-land streams. The establishment is able to produce salmon in closely-controlled conditions which are well-protected from disease. After approximately 5 years of operation, it ran into a major marketing snag, one it's overcome with new marketing outlets, when their main Canadian corporate customer gave their business to a major aquaculture corporation with substantial open cage activity in southern New Brunswick.

The establishment gets Arctic char fingerlings from the inland operation, and elsewhere, fingerlings which they raise. The manager, a person with long experience in the industry, believes exposure to salt water improves the taste and texture of the char. The operation also gets Atlantic halibut from the South Shore of Nova Scotia for grow out. These improvements may come at the expense of some growth. The halibut, which may look unattractive, are nevertheless profitable. In some senses, the halibut, with more limited movement, are like "couch potatoes", because they don't waste energy. And when oxygen becomes less available, halibut breathe more slowly.

Further, the company raises Atlantic salmon smolt from about 30 to 50 grams, and take them to the 75 gram stage. The smolt are acclimatized to salt water, and shipped to Newfoundland via the inland establishment for growout in southern Newfoundland operations. The grown salmon are returned to a plant in New Brunswick to be slaughtered, and shipped.

The establishment has the advantage of very clean water, both fresh and salt, which is taken from the wells. The salt water is very clean, because pathogens have been filtered by the gravel between the wells and the ocean. The four salt and one fresh wells also create a geothermal effect, as the water is never as cold as open water in the winter (never less than 3 to 4 degrees C), and never as warm in summer (a maximum of 12 to 13 degrees C).

The facility does no cage farming. It has four older tanks inside a building immediately adjacent to the main office. There are 12 more tanks, with covers, outside, and two more very big tanks in another shed toward the rear. There are three other staff members at the operation, plus a young student who works on the weekends. The staff are all local, and do not have prior skills in aquaculture. Since they are untrained, a considerable amount of time has to be spent on instruction. While the workers' major expense housing is very low in the adjacent county (perhaps CAD$30,000 for a home) those with education tend to come with certain salary expectations. The establishment is running "too close to the edge" right now to attract trained staff.

There is another community issue, one which concerns business success. Established locals may be a little unhappy about their success, and the staff has to be careful in their local activities. There have been suggestions that closures in local clam fishing are due to aquaculture waste, but the closures have been based on coliform counts, and human waste materials from septic tanks. To compensate, the facility has to try to purchase as much of their power, fuel, groceries, and vehicle repair in the area as they can.

The company expects expansion of the operation in the medium term. It currently has 100 to 125 tonnes capacity, and it will grow much larger in the long term. The company has funding, and grants from the Canadian Department of Fisheries and Oceans (DFO), now in place to build four new bigger tanks and a building for eight tanks. The facility reuses water at a 75 percent level, which is their probable maximum. The staff wants to get into polyculture, with a combination of mussels and seaweed producing a close to pure effluent. While there are no easy measures of relative effluent discharges with which to compare open-cage and closed containment aquaculture, this particular site, by using very clean inputs, and by specializing in high-value, but relatively low volume production, probably compares quite favourably, both environmentally and economically, with its open-cage counterparts, even in the region.

Interestingly, the operation is below sea level at high tide (there have been questions about the security of the seawall on this part of the Bay of Fundy). It has one legal advantage, and that is the fact the area is zoned for aquaculture. It provides them with freedom they might not otherwise have. The pictures below represent both an interesting set of locational decisions, and a cutting edge of closed containment aquaculture to date (Figures 1, 2, 3 and 4).

Closed containment in a world of open systems: case 4

One of the clearest experiments in closed containment aquaculture has recently opened on the Avon estuary, also in close proximity to the Bay of Fundy. It is a small place, with perhaps "half a gas station". The physical plant consists of a Quonset hut which measures 12 m wide and 128 m long. The building contains eight tanks, in two banks of four. The first row contains tanks which are 3 m in diameter, and 1 m in depth, while the second row has tanks which are 6 m in diameter, and 2 m in depth. The smaller tanks are for the fry, and the bigger for grow-out. The Arctic char are graded into 2 size categories. The fish are raised with technology which the owner perfected for use in public aquariums. Power costs are a significant factor, and the company would welcome the development of "green" power.

The plant operates a strict closed cycle, with water brought from the sea being sterilized with ozone to kill off any diseases, and fry being brought in are tested for infection in conjunction with Canadian health authorities (as a consequence of these steps, drugs are not used during the growth cycle). Further, the organic effluent is collected before the water from the tanks is returned to the sea (the intent is to use the organic material for fertilizer). "The water that returns to the sea is cleaner than the water in the sea". The facility does use fish meal which contains fish protein, like anchovies, because the char don't like pellets which substitute vegetable materials.

The "fresh plate" market is in Europe, for 0.5 to 0.75 kg fish; fillets between 0.75 and 1 kg will go to New York. In addition, there is a "live" market among Asians in Toronto.

Figure 1 West Advocate Harbor NS. Looking at a north side view.

Figure 2 West Advocate Harbor NS. Looking up the roadway to the west.

The company's fish is of such high quality that it is receiving acceptance and promotion by Slow Food in Nova Scotia. It is also aiming at "white tabletop" and catering (airline) trade. Their product is sufficiently good to have attracted offers from one upscale hotel chain, as the chain wants land-based fish, and is prepared to pay a higher price for them. The aquaculture operation ships product to market at cooler temperatures-perhaps 7 or 8 degrees C.

The company is hoping to go to market soon with their first products, but they have run into some hurdles with DFO regarding transfers. They were permitted to bring in fry from a hatchery in northern France (only 24 hours away, through Heathrow). However, DFO is now raising some questions about exporting live fish which hasn't gone through quarantine procedures similar to the incoming fry. The Canadian Food Inspection Agency is slated to take over the process of inspecting fish products.

The aquaculture company hopes to start expanding next spring, with expectations for substantial expansion (including a hatchery) on the same site. It would like to attract substantial private and public to permit major expansion. It would also like to set up other

Figure 3 West Advocate Harbor NS. The owner's grandson counts live salmon on to the truck heading to NL. The salmon will grow another 12 months there before going to the grocery store.

Figure 4 West Advocate Harbor NS. Driftwood and gravel between the site and the ocean. Mother Nature's natural sea wall.

operations, closer to their markets around North America. For example, they could raise halibut in an industrial park in Toronto.

Discussion and conclusion

The post-industrial future of closed-containment aquaculture is complex. It does appear to offer some 'niche' prospects which will complement other forms of food production. It also seems to provide some improvements on what has become industrial-scale open-pen aquaculture, even in the industrial north. Places like Atlantic Canada, with an extended coastline, a strong traditional fishing tradition, relatively cheap labour surpluses located in rural areas, and the possibility of considerably cheaper energy sources from wind and tide, appears to be one of the preferred sites on the periphery of major industrial systems. However, as discussed above, progressive post-industrial developments require a reasonably favourable sociopolitical environment. The current social democratic government of Nova Scotia is vigorously pursuing alternative energy resources but, like other traditional social democratic parties, has a weakness for large-scale economic projects as a solution for economic woes. In particular, the current New Democratic Party (NDP) government has given approval to the region's largest corporate organization, based in New Brunswick, to expand its open-pen aquaculture into Saint Mary's Bay in southwestern Nova Scotia. Despite vigorous local opposition, particularly from the lobster industry, the one lucrative fishery left, political approval for open-pen aquaculture is going ahead. While the NDP may well argue the two types of aquaculture are compatible, the initial perceptions are not good. One can put this political complexity in the broader framework of ecological modernization but, especially in a North American context, the perspective raises serious questions about the future of this new form of aquaculture. While ecological modernization is more of a theoretical "patch" on traditional modernization theory than a genuine new viewpoint, it does acknowledge the flexibility of contemporary capitalism to generate new technological environmental innovations. And, in Buttel's view, ecological modernization also creates room for adaptive new state structures which are capable of incorporating both effective corporate systems and "various groups in civil society" (Buttel, 2000, p. 63).

Alternatively, some prefer to focus on the dark side of contemporary modernism, one which functions "within the realities of an economic system that reduces 'green' to a niche market." (Dunham-Jones, 2007, p. 45). Regardless of the particular intonation, it is clear that interpretations of industrial modernism are contested ones, even at the political level.

The challenge, for closed-containment aquaculture, and other post-industrial enterprises, is to avoid absorption in centralizing corporate structures, while at the same time maintaining horizontal linkages with the rural communities in which they are currently based. One useful strategy is ownership, personnel and operational linkages among the four establishments discussed in Cases 1 and 3. These ties create a set of economic and social bonds which help businesses located in a marginal industry both cope in a demanding global marketplace, and facilitate growth. But the first generation of open-cage aquaculture failed this challenge: the verdict for open-cage endeavours remains open. Nevertheless, the precedents, even in the social democratic systems of the industrial north, have not been long term successes. Further, despite the various advantages which closed-containment may have for the local ecology, criticism is beginning to emerge about its externalities. For example, Ayer and Tyedmers (2008), in a life cycle assessment (LCA) of three types of closed-containment systems - marine floating bag, land-based saltwater flow-through, and land-based freshwater recirculating,- suggest that all, to varying degrees and on varying dimensions, may contribute disproportionately to global warming, resource depletion and acidification. These effects are primarily due to the higher costs of creating close-containment infrastructure, and energy costs. They propose that we may be observing "unintended problem shifting", where "potential reductions in local impacts" mask "a range of global scale concerns" (p. 259).

One of the ironies, as we shall discover in considering our four case studies, is the fact that, as one more nearly approximates closedness, under current conditions, the greater that current technological requirements pull the existing experiments towards incursions on the more distal environmental conditions which may determine our future. The only way out of this contradiction may well be the development of greener sources of energy. Not only did a couple of our far-sighted informants mention the desire for greener energy, but Nova Scotia, with new hydro-electric sources in Labrador, and the possibility of capturing tidal power from the Bay of Fundy, may actually be an excellent location for escaping a major twenty-first century bind. Thus, the extent to which closed containment aquaculture may succeed commercially is to some extent bound to the development of post-industrial sources of energy.

Some socio-economic factors which are hard to include in any assessment of costs and benefits are the impacts of social visibility and economic alternatives. Given the human population concentration along the British Columbia coastline, net pens become a decidedly greater irritant where NIMBY considerations are in play. Further, in the presence of diversified economies which provide reasonable alternatives for production and employment, it is relatively easier to criticize any industry with numerous demonstrable environmental impacts.

Finance is another asymmetry which has to be taken into account. Closed containment experiments in North America, like many other small- or intermediate-sized businesses, are somewhat handicapped financially, at least in comparison to western European firms.

As numerous informants have commented, North American banks typically have shorter time lines on their loan terms, and are less willing to support the three to five year plans frequently required.

And one must also take account of environmental innovations which promise positive changes for both closed and open forms of aquaculture. The emergence of various forms of multi-trophic aquaculture will benefit aquaculture generally. Whether one is employing “organic extractive aquaculture species” like shellfish or lobster, or “inorganic extractive aquaculture species”, like seaweeds, to diminish the amount of food, nutrients and waste products, both forms of aquaculture may benefit (Chopin et al. 2010; Kim et al. 2010; Robinson et al. 2010). What is not clear, at this point, is the relative portion of improvements which each form of aquaculture may experience.

Finally, one must consider the micro-social impact of closed containment aquaculture. At one level, given the increasing technological requirements of production, one may observe a diminishing number of labourers, most of whom are expected to bring more education and training to the worksite. While this may be in keeping with the demands of post-industrial transformation, changing fundamentally rural work sites poses a number of challenges. Lower pay rates make it more difficult to recruit skilled labour, even where the cost of housing may be an offsetting factor. The location of two of these sites on Mi’kmaq reserves creates perhaps welcome pressure to upgrade the education and skill levels of workers. In fact, one of the sites imposed a requirement, after initial closure, that potential employees obtain education in aquaculture at a nearby community college.

Whatever the qualifications at a post-industrial level, one does need to recognize the tighter human-technology bonds, the increased complexity of machine-human systems, or cyborgization, of the new operations. Actor-network theory remains a useful approach to aquaculture generally, and to closed containment aquaculture in particular. As new assemblies of society, technoscience and nature, closed containment experiments are definitely projects "in the making" (Skladany, 2000: 275). Actor-network theory, in its fascination with the problematic construction of new assemblies, where a considerable number are subject to failure, is admirably suited to a new endeavour which is strongly dependent on the development of new, and commercially successful, forms of both technoscience, and career lines in technoscience. The closed containment experiments we have examined have required arduous, time-consuming efforts to reshape material and social environments. Several have failed, and been reborn, due to environmental challenges-either diseases or inadequate marine conditions. Another failed due to its inability to assemble a workforce sufficiently educated and skilled to operate the technostructure efficiently. And their futures remain open, with the odds against some quite long. Nevertheless, each of the cases we consider in this essay remain in business at the time of writing. Like theoretical predecessors of very different persuasions-exchange theory and symbolic interactionism-actor-network theory, insofar as it recommends a set of methodological prescriptions, does focus on various actors, and does start at an analytic micro-level. Despite claims which parallel its predecessors, actor-network theory believes it can build upwards to an adequate theory of social structure. However, its primary contributions have been to laboratory work in the natural sciences, and its extensions into the broader material and social world. The new closed containment case studies all involve personnel with considerable scientific training in aquaculture-at least three have Master's degrees in aquaculture, and one is a doctorate with lengthy experience in fish farming of different sorts. All are taking considerable risks in trying to establish new scientific and technical arrays which can be successfully combined with new labour force strategies and new markets. One establishment has had to completely replace its workforce of fifteen with workers possessing more education and work discipline. Others have attempted to create desirable living arrangements to facilitate the recruitment of skilled labour. And there have been varying approaches to the market, ranging from the local, to the regional and the national. Which of these various endeavours, if any, will succeed, remains to be seen.

While one may be inclined to assert the continuing primacy of human activity in such systems, the balance is beginning to shift in ways that ought to make us a bit uncomfortable. Post-industrial systems began with considerable promise, but are bending, under continuing economic pressure, to provide benefits for the upper tier of an increasingly stratified society. Sustainable, high-quality food is a laudable goal, but only if one can create market structures which assure that the new beneficence is more equally shared.

But this debate has just begun. As with the earlier round of contention surrounding net pen aquaculture (Bailey et al. 1996), the arguments about closed containment are in their early days. And we need to constantly remind ourselves that these contentions, while they may be framed in the scientific, economic and technological language employed have irreducible social elements.

Endnotes

[a](Belton et al. 2009) cautions that sustainability dialogues and certification may be coopted by larger, more capital-intensive enterprises, in conjunction with certification programs, by emphasizing the technical, rather than the social, dimensions of their activity.

[b]While there appears to be no definitive proof about the arrival of MSX, which has existed in the Chesapeake Bay for some time, it is widely suspected that industrial vessels coming to Little Narrows to load gypsum, and return it to the American northeast, emptied ballast water containing parasites with MSX (Parker et al. 2007). There have also been suggests that Prince Edward Island and New Brunswick will eventually develop MSX. Indeed, it is possible that some unexplained "die-offs" in Prince Edward Island may be attributable to MSX. One underlying causal mechanism is believed to be the gradual increase in water temperature attributable to global warming.

[c]The problem faced by many of these new operations is the comparatively large amounts of capital required to fund and operate grow-out operations proper. In the absence of sufficient capital, firms may be reduced to hatcheries, as well as initial, but not final, sites for full development of the fish. I thank Peter Corey for this point.

[d]There has been a another closed containment grow-out site for Arctic char located on the Millbrook Reserve near Truro. The site, as constructed, was designed to convert wastes into non-toxic nitrates which could either be disposed of in the municipal sewage system, or utilized in an associated greenhouse to help grow aquaponic bedding and annual plants (Barratt 2006; Bourque 2003). However, the facility encountered economic problems, and was closed for a number of years. It is now reopened, with a managerial and marketing connection to the Avon facility discussed below. The greenhouse is now being run as a separate economic organization.

Competing interests

The author declares that he has no competing interests.

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