Investigation into the sustainability of organic aquaculture of Atlantic cod (*Gadus morhua*)

Benjamin Birt, Lynda D. Rodwell, & Jonathan P. Richards

School of Earth, Ocean and Environmental Sciences, University of Plymouth, Portland Square, Drake Circus, Plymouth PL4 8AA UK (email: benbirt2@hotmail.com)

Wild stocks of Atlantic cod (*Gadus morhua*) are low. With fisheries in decline, continued demand for cod has led to a fledgling aquaculture industry and current forecasts call for rapid growth. However, critics blame aquaculture of carnivorous species for further depleting fish stocks and for its wider effects on the marine environment. We examine the activities of Johnson Seafarms, a sea-cage organic cod farming facility in the Shetland Islands, to investigate whether “organic” cod farming can be environmentally, economically, and socially sustainable. Data were collected via public questionnaires and interviews with aquaculture experts. The results show that, before it closed in 2008, Johnson Seafarms was addressing the environmental concerns traditionally associated with aquaculture of carnivorous species and that economic viability is possible as a market exists for organically farmed cod at prices higher than for wild fish. We conclude that organic cod farming, as was practiced in the Shetland Islands, is sustainable on that scale. While the industry has room for measured expansion, over expansion would increase pressure on natural systems, undermining environmental and, ultimately, social and economic sustainability. Producers and regulators should consider alternative techniques, including land-based or integrated aquaculture systems. Any development should be accompanied by further research regarding the industry’s sustainability.

KEYWORDS: marine aquaculture, cages, environmental effects, sustainable use, socioeconomic aspects, organic farming

Introduction

Global fisheries are in decline, with over two-thirds of marine fisheries fully exploited, overexploited, or depleted (Naylor et al. 1998; 2000; FAO, 2000; 2006; Pauly et al. 2002; Naylor & Burke, 2005; Jacquet & Pauly, 2007). In particular, stocks of Atlantic cod (*Gadus morhua*) are dangerously low across nearly all of the species range that extends across most of the North Atlantic continental shelf, with catches declining significantly in recent years (Myers et al. 1997; Brown et al. 2003; Rosenlund & Skretting, 2006; ICES, 2007). In the North Sea, the eastern part of the English Channel, and the Skagerrak Straight (located between Denmark and Norway), 95% of cod from each year class is caught before the fish have spawned (ICES, 2007). Wild cod populations are unlikely to recover in the next decade, even if the European Commission were to implement more effective management procedures (Horwood et al. 2006) and cod aquaculture is likely to expand as capture fisheries continue to decline (Brown et al. 2003; Lee & Connelly, 2006; Rosenlund & Skretting, 2006).

Environmental concerns though have led to questions about the ultimate sustainability of the aquaculture industry (Pauly et al. 2002; Powell, 2003; Pauly, 2006). While most research focuses on salmonids, the ongrowing stage of sea-cage cod farming (where fish are kept and fed in cages at sea) is nearly identical to that of salmon in terms of techniques, suitable locations, technology, equipment, and husbandry practices, and existing salmon infrastructure can often be used for cod farming (Walden, 2000). In this way, many concerns over salmonid farming are directly relevant to cod operations.
First, the effects of effluent discharge in the form of excessive nutrients from sea-cage farming is a long-standing issue (Folke et al. 1994; Gowen, 1994; Naylor et al. 1998; 2000; Powell, 2003; Goldburg & Naylor, 2004; Naylor & Burke, 2005; Kjesbu et al. 2006). Abnormally high levels of nutrients can alter the structure of benthic (seabed) ecosystems and cause algal blooms that are toxic to fish and shellfish (Anderson et al. 2002).

Second, escaped fish can pose risks if they are significantly different from their wild counterparts either through genetic selection or by being nonnative species (Kapuscinski & Hallerman, 1991; Soto et al. 2001; Naylor et al. 2005). Although cod farming is in its infancy and the effects of escapes are unproven (Dahle et al. 2006), genetically distinct subpopulations of cod exist, so escapes could have negative implications should escaped and wild fish interbreed (Brown et al. 2003; Jørstad, 2004; Bekkevold et al. 2006).

Third, the spread of disease to wild fish can have detrimental effects on the wider ecosystem (Goldburg et al. 2001). For instance, sea lice (Caligus spp) infestations within salmon farms are regarded as responsible for wild fish found with attached sea lice (Naylor et al. 2003). Infestations can prove fatal to fish and early studies indicate that sea lice affect cod (Walden, 2000). As cod farming develops, new diseases are likely to appear (Kjesbu et al. 2006), as indicated by the outbreak of Franciscella in one cod farm in Norway that saw a 40% mortality rate over a five-month period (Fish Farmer Magazine, 2006).4

Finally, reliance on wild-caught fish in aquaculture feed has attracted criticism since aquaculture operations for carnivorous fish can contribute to fishing pressure on certain stocks, such as the Peruvian anchoveta (Engraulis ringens) and Chilean jack mackerel (Trachurus murphyi) (Naylor et al. 1998; 2000; Pauly et al. 2000; Hannesson, 2003; Powell, 2003; Asche & Tveterås, 2004; Naylor & Burke, 2005; Kjesbu et al. 2006; Opstad et al. 2006).

Despite these concerns, some researchers see Atlantic cod as a promising species for aquaculture operations for carnivorous fish can contribute to fishing pressure on certain stocks, such as the Peruvian anchoveta (Engraulis ringens) and Chilean jack mackerel (Trachurus murphyi) (Naylor et al. 1998; 2000; Pauly et al. 2000; Hannesson, 2003; Powell, 2003; Asche & Tveterås, 2004; Naylor & Burke, 2005; Kjesbu et al. 2006; Opstad et al. 2006).

Large-scale production is an objective in Norway, despite concerns about the negative environmental effects of expansive, modern aquaculture operations (Naylor et al. 2000; Pauly et al. 2002). Johnson Seafarms (marketing its cod under the brand name “No Catch”) in the Shetland Islands took a different approach based on the notion that cod could be farmed sustainably with minimal negative environmental impact. We investigate this assertion. Although Johnson Seafarms declared bankruptcy in 2008 and was forced to close after incurring unmanageable debts, the environmental and economic principles inherent in the operation remain relevant.

Several recent studies focus on aquaculture’s sustainability (see, e.g., Costa-Pierce, 2002; Naylor & Burke, 2005; Dallimore, 2006), but there is a dearth of literature specifically on organic cod farming. Because of the novelty of this activity, research to date on the potential for cod farming in the Shetland Islands has not considered the possibility of environmental impacts or the opportunity to develop organic sea-cage aquaculture systems (Walden, 2000). Johnson Seafarms, the world’s first organic cod farm, provides a useful case study to begin to ameliorate this paucity of published work. The idea of a “sustainable management strategy” for cod aquaculture might include criteria that define organic cod farming and set guidelines detailing industry best practices (Dahle et al. 2006). Johnson Seafarms received organic certification from the Organic Food Federation (OFF), having fulfilled the organization’s criteria regarding issues such as local environmental impacts, feed ingredients, vaccines and antibiotics, and stocking densities (OFF, 2005). However, other credentialing bodies have their own similar—though competing—guidelines and harmonization of these protocols seems desirable (Hepburn, 2004; OFF, 2005).

This article investigates whether organic cod farming can be environmentally and economically sustainable and poses the question: “Can this practice go on indefinitely in this location?” We also consider the industry with respect to social sustainability. A description of the basics of cod farming is followed by a summary of the research methodology that comprised the collection of quantitative data through closed format questionnaires and qualitative data via interviews with a range of aquaculture experts. We then display and discuss our results and present our conclusions regarding the sustainability of organic cod aquaculture.

---

4 Externally, cod infected by Franciscella exhibit few symptoms other than a reduced appetite and poor swimming. Internally, organs swell and develop white granulation tissue.

5 The Organic Food Federation (OFF) standards for cod aquaculture have been approved by the Department for Environment, Food and Rural Affairs (DEFRA) in the United Kingdom.
The Basics of Cod Farming

The process of farming cod can be broken down into three phases: hatchery/nursery in tanks on land, “ongrowing” in sea cages, and processing (slaughtering the fish and preparing them for market). Wild caught fish are kept in tanks on land and used as the broodstock to produce fish for the farm. When they first hatch, young cod spend six to eight days still attached to their yolk-sacs, gradually making the transition to feeding on plankton. After 35 to 40 days, the young cod move to a diet of dry feed and remain in on-land tanks until they reach six to seven months old-and a weight of 20-50 grams. At this stage, they are transferred for ongrowing in sea cages until harvest at around three years of age and 2-5 kilograms (Walden, 2000). As pictured in Figures 1 and 2, sea cages are floating, netted enclosures suspended in the water and anchored to the seabed.

The Johnson Seafarms operation included the hatchery, nursery, ongrowing, and processing stages of the farming process, employing up to 130 people at its peak. The company employed scientists for research and monitoring, technicians and engineers to operate and maintain the cages and other equipment, factory workers to process the fish, and a range of office staff. With almost 30 cages (farming salmon and sea trout as well as cod) in twelve locations, the business produced 2,500 metric tons (mt) of cod in 2007, just prior to bankruptcy. In 2008, the company’s creditors took possession of 3,000 mt of cod, a small amount compared to projected production of 30,000 mt of organic cod by 2012 (10% of the forecasted demand for the United Kingdom). After failing to find a buyer to maintain organic cod production, the creditors closed down the operation and sold the entire business to conventional salmon-farm interests.

Research Methodology

To assess the potential economic success of organically farmed cod, we administered a public survey to gauge consumer willingness to pay for fish produced under such circumstances. Quantitative data were collected through two closed-format questionnaires. We administered the first survey to twenty customers in each of four fish-and-chip shops in different areas of Plymouth and two in Totnes (southeastern United Kingdom) for a total of 120 respondents. We chose two different geographic areas to achieve a diverse range of survey participants and selected fish-and-chip shops specifically for two reasons. First, we assumed that a high percentage of customers would eat cod and, therefore, provide useful data about their perceptions of the farmed variety. Second, we felt the face-to-face method, where, with the consent of the shop managers, respondents were approached after placing their order, was less intrusive than a street survey while they were eating their meals. We also assumed this approach would generate a higher response rate than other methods (de Vaus, 2002). We administered the second questionnaire to fifteen managers of Plymouth’s fish-and-chip shops to gain cod sellers’ perspectives on selling farmed cod.

We tested the majority of the data collected from both questionnaires for significance using one-sample chi-square tests or chi-square tests for independence, while a Friedman test was used where responses were in the form of rankings. A one-way repeated-measures ANOVA was employed to analyze data from the shop managers regarding cod prices, although the small sample size might have significantly reduced the power of this test.
The research team also collected qualitative data using a series of questions put to a range of aquaculture experts with differing backgrounds and perspectives (Table 1). Although we used a basic set of questions, respondents were encouraged to expand upon their answers if they saw fit to do so. For this reason, the interview technique can be described as either semistructured or unstructured. We employed a thematic “framework” analysis to sort and analyze the data, taking care not to lose sight of the original context when removing sections of text from the full transcripts (see Ritchie & Spencer, 1994).

Results

We tested the data generated by the responses to each section of both questionnaires for statistical significance. Based on the surveys, it is not possible to identify any correlation between consumers’ knowledge of environmental, ethical, or sustainability issues concerning cod and their behavior when choosing a particular type of cod. The results of a one-sample chi-square test for statistical significance were inconclusive ($\chi^2=0.03$, $p=0.86$), the data showing a near 50-50 split (59 aware, 61 not aware) of how many respondents were familiar with such issues (Table 2).

A one-sample chi-square test showed a high level of significance ($\chi^2=77.89$, $p \leq 0.05$), suggesting that very few people in the target population inquired about the origin of the cod that they ate (Table 2). This finding suggests that farmed and/or organically farmed cod may have a market regardless of consumer opinion. In other words, as many people did not know where their fish came from, they would be likely to eat farmed cod without knowing it.

We used a chi-square test for independence to determine whether awareness of farmed cod was independent of awareness of the organically farmed variety. Knowledge of the existence of farmed cod was significantly higher than organically farmed cod ($\chi^2=15.65$, $p \leq 0.05$), about which only nine respondents had any familiarity. This result shows the need for more public education if farmed, and particularly organically produced, cod is to become widely recognized by consumers.

Results of one-sample chi-square tests ($\chi^2=34.35$ and 38.15, $p \leq 0.05$) were shown to be statistically significant in that a high percentage of people would consider eating both farmed and organically farmed cod (Table 2). A chi-square test for independence ($\chi^2=229.55$, $p \leq 0.05$) showed that those who would eat farmed cod are also more likely to eat organically farmed cod.

A one-sample chi-square test ($\chi^2=86.56$, $p \leq 0.05$) showed only a small minority (5/120) of respondents to oppose a fish farm in their local area (Table 2). Although the south of England may be unsuitable for cod farming, this result hints that expansion of cod

Table 1 Interview respondents.

| Respondent | Affiliation/Interest |
|------------|----------------------|
| Johnson's Scientist A | Johnson Seafarms Ltd, Shetland |
| Johnson's Scientist B | Johnson Seafarms Ltd, Shetland |
| On-land Aquaculturist | Owner & Operator, Jersey Turbot, land-based aquaculture facility, Jersey, British Isles |
| Scientist A | University of Stirling, Institute of Aquaculture, Marine Environmental Research Laboratory, Scotland |
| Scientist B | School of Biological Sciences, University of Plymouth, UK |
| SEPA Representative | Scottish Environment Protection Agency (SEPA) |
| Conservationist A | Writer and journalist with an interest in aquaculture; formerly with The Salmon Farm Protest Group, UK |
| Conservationist B | Marine Conservation Society, UK |

Table 2 Public questionnaire: summary of questions and results.

| Question | N | Yes | No | Maybe | Mean | Standard Deviation | $\chi^2$ | Significance (p) |
|----------|---|-----|----|------|------|-------------------|--------|-----------------|
| Are you aware of any environmental, ethical, or sustainability issues concerning cod? | 120 | 59 | 61 | – | 1.51 | 0.502 | 0.03 | 0.86 |
| Do you check which geographical area your cod comes from? | 104 | 7 | 97 | – | 1.93 | 0.252 | 77.89 | 0.00 |
| Are you aware of the existence of farmed cod? | 120 | 46 | 74 | – | 1.62 | 0.488 | 6.53 | 0.01 |
| Are you aware of the existence of organically farmed cod? | 120 | 9 | 111 | – | 1.93 | 0.264 | 86.70 | 0.00 |
| Would you eat farmed cod? | 120 | 69 | 18 | 33 | 1.58 | 0.741 | 34.35 | 0.00 |
| Would you eat organically farmed cod? | 120 | 71 | 18 | 31 | 1.56 | 0.742 | 38.15 | 0.00 |
| Would you be happy for fish farming to exist in your area? | 120 | 86 | 5 | 29 | 1.33 | 0.552 | 86.55 | 0.00 |
farming might not run contrary to public opinion. More research, however, would be needed in appropriate locations before drawing conclusions on this point.

Only two of the fifteen shop-manager respondents would not serve farmed or organically farmed cod. While a chi-square test for independence proved significant ($\chi^2=16.16, p \leq 0.05$), two one-sample chi-square tests (both $\chi^2=5.20, p=0.07$) were not statistically significant. The data here show a majority (nine respondents) answered “maybe” to this question, citing customer opinion as the factor that would determine their fish-selling policy (Table 3).

A Friedman test to investigate the consistency of responses suggests significant differences between how much people were willing to pay for the three types of cod (wild cod from a sustainable capture fishery, conventionally farmed cod, and organically farmed cod) compared to standard wild cod ($\chi^2=94.43, p \leq 0.05$). Respondents were willing to pay a mean premium of up to 50 pence (US$0.82) for an average sized portion of cod (150 grams) from a sustainable capture fishery above that for a similar meal prepared from standard wild fish and a premium of up to 25 pence (US$0.41) for organically farmed cod. Farmed cod was the least popular with consumers, who were willing to pay 25 pence less (Table 4).

A one-way repeated-measures ANOVA test looked for differences between respondents. The test provided no statistically significant information on the prices that shop managers were willing to pay for the three types of cod ($F=2.35, p=0.14$) (Table 4). Wholesale prices for cod fluctuate greatly, as the supply levels are not always guaranteed due to changeable weather and fish abundance, and it proved difficult for respondents to provide meaningful specific figures. In addition, the shop managers were keen to demonstrate the importance of customer opinion in influencing the type of fish they sold as well as its price, implying that an important driver for any future farmed cod market will be the customers. It should be noted that the small sample size might have reduced the power of the ANOVA test in this case.

**Discussion**

With consumer demand for cod set at current levels, it seems unlikely that farming can entirely replace wild fisheries purely in terms of production volume. Even though Norway has the potential to produce over 500,000 mt of cod per year from aquaculture (Adoff et al. 2002), Scientist B reminded us that in the United Kingdom the scope for expansion is limited, with cod farming only practical in colder waters such as Scotland and its islands. On the other hand, the amount of adaptation of existing infrastructure required to convert a salmon farm into a cod farm is minimal. Whether the switch from salmon to cod will occur is not yet clear, but Conservationist A sees it as a distinct possibility and notes that “because of the [negative] reputation that salmon farming has

| Table 3 Shop manager questionnaire: Would shop-managers sell farmed/organically farmed cod? |
|---------------------------------|-------|-----|-----|-------|-----|-----|
| Question                        | N     | Yes | No  | Maybe | Mean | Standard Deviation | $\chi^2$ | Significance (p) |
| Would you sell farmed cod?      | 15    | 4   | 2   | 9     | 1.87 | 0.640              | 5.20     | 0.07              |
| Would you sell organically farmed cod? | 15    | 4   | 2   | 9     | 1.87 | 0.640              | 5.20     | 0.07              |

| Table 4 Prices willing to be paid for three types of cod by customers and shop managers. |
|-------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|
| Question                                         | N   | Mean | Standard Deviation | Mean | Standard Deviation | Mean | Standard Deviation | Statistical test |
| How much would you be willing to pay for the following types of cod and chips? (Customer) | 102 | Up to 25p less than currently | 1.32 | Up to 25p more than currently | 1.49 | Up to 50p more than currently | 1.17 | Friedman $\chi^2=94.43, p=0.00$ |
| How much would you be willing to pay per pound for the following types of cod? (Manager) | 13  | £2.50 | 24.50 | £2.61 | 34.60 | £2.51 | 25.34 | ANOVA $F=3.35, p=0.14$ |
garnered for itself, a lot of the salmon farmers would be very happy to change to cod.” One possible barrier to an expansion of cod farming through a switch from salmon farming, pointed out by Conservationist B, is climate change and the anticipated rise in water temperatures. This will further shrink the area conducive to farming cod.

For Scientist A, “any expansion comes down to basic economics—you have to make money doing it,” and although the Scottish Environment Protection Agency (SEPA) representative believes that “in the medium to long term, it is possible that farmed cod will replace caught fish,” the need to establish economic success is essential if the industry is to create a platform on which to grow. In its early stages, Johnson Seafarms appeared to be a prime example of potential economic viability in the present market. Although cautious in being too quick to claim economic success, Johnson Seafarms Scientist A comments that the company did not “need to be hitting the same market as wild fisheries” as its product was “driven towards the high end of the market,” summing up well the economic intentions of the Shetland Islands’ only cod farm. Support for the economic viability of niche-market aquaculture also comes from the SEPA representative, the on-land aquaculturist (who has successfully exploited a niche in his local seafood market), and the two scientist respondents.

In addition, the survey data demonstrate that organically farmed cod consistently ranks higher than farmed cod in popularity and imply that shop managers would base their decisions about what type of fish to sell on customer opinion (Table 4). The willingness of respondents to pay more for organically farmed cod and the lack of opposition to local cod farms (a purely hypothetical concept due to climatic constraints) both give credence to the idea of successful niche markets.

The eventual failure of Johnson Seafarms’ No Catch venture weakens the argument for economic sustainability based on niche markets. However, the demise of one operation does not undermine the workability of the general concept. Several factors were involved in the company’s ultimate closure. First, the organic status of the cod facilities meant higher overall operating costs. Feed costs were between 15 and 20% higher than for a conventional cod farm and the organic certification required lower stocking densities (Fish Farmer Magazine, 2008). In addition, the bankruptcy administrators point to an ongoing battle to increase the knowledge of growth curves for cod, decrease mortality rates, and lower production costs (Fish Farmer Magazine, 2008).

However, based on the experiences of organic operations for other species such as salmon, Johnson Seafarms’ management would have been able to anticipate many, if not all, of these costs so they do not, on their own, explain the ultimate collapse. A key factor in the dissolution of the company was the global credit crunch and resulting financial crisis, with the principal creditor, the Icelandic bank Kaupthing, calling in loans in February 2008, just before an economically important harvest was ready (Carrell, 2008; Clover, 2008). The lack of a pre-existing model on which to make financial or business forecasts is also likely to have played a part. Johnson Seafarms seems to have suffered for being a market innovator.

Despite the company’s eventual closure, managers and bankruptcy administrators alike remain confident that organic, sustainable cod farming can be successful (Carrell, 2008; Clover, 2008). Future organic farms will have to contend with higher production costs than conventional operations, but Johnson Seafarms demonstrated that consumers were willing to pay a premium for their product that was approximately 50% higher than the price for wild cod. In addition, technological advances that the company made will benefit future cod operators. It seems likely that, given a more favorable economic climate and with careful management and solid financial backing, future organic operations could achieve extended success.

Experience with salmon farming shows that employment levels on fish farms can significantly decline over time as efficiency increases. Figures from the Scottish Executive (2006) show that between 1995 and 2005, Scotland’s farmed salmon production rose from 70,060 to 129,588 mt, while the number of staff employed in production dropped from 1,355 to 979 people. Although a highly mechanized and efficient farming system could conceivably be economically and environmentally sustainable, the resulting social effects may be untenable.

However, Johnson Seafarms started positively in terms its recruitment of staff, increasing from about 30 to over 100 employees before the company went into bankruptcy (Johnson Seafarms Scientist B). If a future operation were able to maintain relatively high employment figures, the employment benefits to local communities would be significant, meaning social sustainability may well be attainable. This might be more achievable if organic cod aquaculture were...
practiced on a “smaller unit basis rather than by vast corporations” (Scientist B). Scientist B’s reasoning stems from the tendency for the drive for greater efficiency in large-scale operations to substitute mechanical alternatives for human labor wherever feasible. Automated systems can largely replace the need for employees for tasks such as monitoring of water conditions and feeding fish.

Several environmental issues associated with sea-cage aquaculture, and the ways in which Johnson Seafarms was addressing them, merit discussion. Due to high fish densities in relatively small areas, disease outbreaks are a significant threat in sea-cage aquaculture. While disease is “not a major problem so far… it is [in its] early days and no doubt it will get worse” (Scientist A). Marine Harvest, with its head office in Norway, is one of the world’s major multinational aquaculture companies and the firm has interests in a number of fish species. It lost a large proportion of its cod stocks in 2005 to a newly observed disease, Francisella (Olsen et al. 2006). Such an episode would have been economically disastrous for Johnson Seafarms because of its reliance on heavy outside investment. The economic implications of a serious outbreak of an untreatable disease are clear. Of concern to the wider environment is the possibility of wild fish contracting diseases by swimming near sea-cages containing infected farmed fish. Again, we see the intrinsic link between environmental and economic health and sustainability. As the industry expands, it will need to place greater effort on sharing information and products (particularly vaccines) between Norway and the United Kingdom. Unfortunately, at present, given that cod aquaculture is a relatively new industry in Europe, regulations do not facilitate this process (Scientist A), leading to concern that potentially avoidable disease outbreaks will occur in the future.

The broodstock used in the organic cod farm in the Shetland Islands was taken from the wild. Therefore, should fish escape, “what [they would] impart genetically on wild stocks wouldn’t be a problem” (Johnson Seafarms Scientist A). However, it appears that with well-maintained double-netting systems, such as those used by Johnson Seafarms, escapes can be minimized, or even eliminated. Nonetheless, in terms of possible industry expansion, regulators must take care, for cod, as a species, is more prone to pick away at the nets than salmon (Conservationist B; Johnson Seafarms Scientist A). If future operations sought to reduce their expenses by using single-net systems, escapes would be more likely. If this scenario were combined with a genetic selection program, where fish were bred to grow quickly in sea cages rather than for life in the wild, questions over sustainability would arise as any mixing might weaken the genetic strength of wild cod populations.

Another contentious subject has been the constant artificial lighting used to prevent sexual maturation in farmed cod by inhibiting the onset of puberty. Such equipment enables operators to reduce mortality and to ensure that more of the food energy given to the fish is converted into flesh. Proponents of the system argue that constant light is beneficial to the welfare of the fish as it prevents maturation—a highly stressful time for fish and a time of significant mortality (Conservationist B; Scientist A; Johnson Seafarms Scientist A). The Organic Food Federation, the organization that granted Johnson Seafarms its organic status, accepts this side of the welfare argument. Opponents of artificial lighting, however, assert that “fish do not naturally live in perpetual light” (Conservationist A). The Soil Association agrees and refused to grant organic status to Johnson Seafarms, commenting that constant artificial lighting is not compatible with its vision of what is organic as it strays too far from the animals’ natural environmental conditions (Poulter, 2007). While we set aside the specific question of fish welfare, energy use is the issue for sustainability that we consider here. Significant electricity is required and research is ongoing to develop low energy forms of light and to experiment with different lighting regimes (Migaud, 2007; Conservationist B).

Loss of fish to predation has long been a problem for sea-cage farmers. The traditional solution to the problem has been to shoot the predators (Scientist B), grey seals in the case of cod. At present, grey seals are not endangered in waters surrounding the United Kingdom, but destroying those parts of the natural setting deemed unhelpful by humans cannot be considered sustainable and seals are a vitally important part of the marine ecosystem (Österblom et al. 2007). Once again, though, Johnson Seafarms had carefully thought-out policies, employing a highly visible top-netting system to deter seabirds and an underwater taut double-netting system to keep out predators.

---

8 See Samuelsen et al. (2006) for a detailed review of the diseases associated with Atlantic cod and their treatments.
9 The disease was previously unobserved due to the relatively short history of cod aquaculture. There is no efficient treatment or vaccine at this stage.
10 The imperfect situation regarding vaccine sharing is a symptom of a relatively young industry in which regulations have struggled to keep pace with vaccine developments. Furthermore, there is little pressure at present to resolve matters as the European Union’s cod production levels are minimal compared to Norway’s.
11 Artificial lighting undoubtedly prevents maturation in cod and therefore reduces mortality. The Soil Association’s refusal to grant organic status essentially hinged on the welfare issue of subjecting fish to 24-hour lighting and on the concept of manipulating their natural life stages.
seals. While these measures entailed added expense and were more time-consuming than traditional, looser, and less visible netting systems that can entangle seals and birds, they had no ill effect on would-be predators and enhanced the company’s claims to be environmentally forward-thinking. Furthermore, the all-important goal of protecting the fish from predators was achieved.

One of the principal barriers to the sustainability of carnivorous aquaculture has been that “to feed the carnivores, fishermen are fishing for fish to feed to fish” (Ellis, 2003). The feed issue is a significant challenge in that many of the fish caught for aquaculture feed could be consumed directly by humans, particularly in developing nations, rather than used for farmed fish that are often expensive luxuries. Various solutions have been suggested, including vegetable protein as a partial or full replacement for fish protein (Scientist A), but increasing competition for space and resources on land might prove problematic (Scientist B; Johnson Seafarms Scientist A).

An option favored by Conservationist B and Scientist B is the use of porcine blood meal, although consumer acceptance is uncertain (Johnson Seafarms Scientist B; Conservationist B).

Johnson Seafarms sourced feed from offcuts from herring and mackerel fisheries. Although this put them in some competition with fertilizer and pet food manufacturers, on the face of it, it is difficult to argue that this practice is unsustainable, as it placed no new pressure on resources. However, one issue might still block the company’s claims to have produced the world’s first sustainably farmed cod, while a second issue could affect the sustainability of future operations.

First, are the herring and mackerel fisheries from which Johnson Seafarms sourced its offcuts sustainable in their own right? In the absence of an independent certification, it cannot be said with confidence that they are sustainable. However, two policies show that the company was moving in the right direction in this area. An initial strategy was a gesture of sourcing from offcuts at all when it would have been significantly cheaper to use fisheries targeting their catch specifically for aquaculture (Johnson Seafarms Scientist B; Conservationist B). A subsequent policy encouraged the Marine Stewardship Council (MSC) to investigate certifying the pelagic fishery from which the company obtained its offcuts (Johnson Seafarms Scientist A).

The second issue regarding sustainability centers on expansion. Given the operating size of Johnson Seafarms, the level of the organic cod-farming industry’s demands on natural capital may well have qualified it for sustainable status but, should future operations prove economically successful, other producers will be tempted to enter the market. Competition for offcuts would increase and new producers might not meet the exacting environmental standards that Johnson Seafarms set for itself (Conservationist B).

Despite these two caveats, Conservationist A feels that MSC certification of feed fisheries would be a significant step toward sustainability, although he does pose the question of who should police the fishery prior to and after such a determination is made. As a result of his years campaigning against the salmon-farming industry, Conservationist A is the first to admit that he has a trust issue. However, he says, “It’s the best we’ve got just now” and the feed issue is a complex one that lacks one single solution (Conservationist B).

Pollution discharges from fish farms can moreover be cause for environmental concern. “Any aquaculture operation is going to have a footprint” (Johnson Seafarms Scientist A). “If you stop for a period of time, the ecosystem should be able to get back to how it was before—that’s the test” (Johnson Seafarms Scientist B). These two comments indicate Johnson Seafarms’ realistic attitude toward pollution discharges. However, comments from Conservationist A about “the amount of pollution that emanates from Scotland’s West Highlands and Islands fish farms,” estimating that “the discharges are equivalent roughly to a population of 10 million people,” are cause for concern. A WWF report quantified the nitrogen pollution as being equivalent to the annual sewage discharges of a population of 3.2 million people, while phosphorous discharges were comparable to those of 9.4 million people (MacGarvin, 2000). The fish-farming industry clearly contributes some pollution to the marine environment, but the regulators claim to have taken a more precautionary approach with cod-stocking densities than with other species by limiting the biomass to 66% of what would be allowed for salmon (Conservationist B; SEPA Representative). The precautionary stocking density appears appropriate given that surveys have shown that the effects of cage discharges from the Shetland site on the seabed were measurable and, although not considered excessive when compared to other species, increased over a three-year period (Cromey et al. 2009).

Although it is difficult to separate cod and salmon farming, as they are part of the larger fish-farming industry, and while taking care not to view cod farming in isolation, discharges from cod farms appear to be lower than from salmon farms. Cod feces are less solid than salmon feces and therefore disperse more easily, thereby reducing the impact on the local environment (Johnson Seafarms Scientists A & B; Scientist A; Conservationist B). Furthermore, with careful feeding regimes, waste feed can be minimized (as it can with all species), something that...
Alternative Aquaculture Techniques

At Jersey Turbot, a facility located on the island of Jersey that grows a species of flatfish, turbot (*Psetta maxima*), in tanks on land, testing of water quality by the Department of Environment, Food, and Rural Affairs (DEFRA) has shown pollution to be "absolutely negligible." This situation would no doubt come as welcome news to one of cage-based fish farming’s most vocal critics, Conservationist A, who commented, “My basis for supporting aquaculture is very simple. Do it on land—land-based, closed-containment systems.” There are reasons for concern. Sea farming in an open system is more prone to outbreaks of disease (Scientist B) while closed, land-based systems are less at risk because contact with wild fish is nonexistent (On-land Aquaculturist).

The environmental advantages of land-based re-circulation aquaculture systems are described by Rawlinson & Forster (2000) who also show that it can be economically viable on several different scales. However, Johnson Seafarms Scientist A questions the economic viability of land-based aquaculture for cod, citing problems of space and energy use in pumping water. His conclusion: “Indeed, it would be possible, but does it make economic sense?” is in line with the Scottish Executive’s summary of the situation (Highlands & Islands Enterprise, 2002). It would appear, therefore, that as long as legislation allows fish farms to be located in the sea, aquaculture producers will favor cage systems.

Scientist B referred to the Blue Water Flatfish project in Anglesey, North Wales, a land-based facility that has taken the step of growing reeds and polychaete worms in the enriched sediment created by the farm’s discharges. Such integrated systems may provide an opportunity for reducing pollution discharges to near zero and research has highlighted the potential of both land-based and sea-based integrated systems (Chopin et al. 2001; Troell et al. 2003; Neori et al. 2004). In addition, the Scottish Executive has shown an interest in combining finfish farming with seaweed or shellfish production (Highlands & Islands Enterprise, 2002). The environmental benefits associated with such systems include their ability to control and reduce pollution discharges associated with fish farms (Wurts, 2000; Frankic & Hershner, 2003), resulting in a shift toward sustainability. Furthermore, Neori et al. (2004) assure us that there can also be economic benefits in the form of high profitability—clearly a vital consideration when assessing the industry’s sustainability from a comprehensive perspective.

Regulations Present and Future and Their Implications

Johnson Seafarms Scientist A, Conservationist A, and Scientist B alluded to the heavy nature of the regulatory framework. Indisputably, the industry is subject to considerable oversight, but it is equally certain that some areas are in need of improvement. Two suggestions are of particular interest.

First, Conservationist A has called for an independent regulatory body for all forms of aquaculture. While arguments might develop over exactly what constitutes an independent regulatory body, and some might say it already exists, an outside authority is desirable to achieve and to maintain sustainability. Second, Scientist B reminds us that the very words “sustainability” and “organic” have yet to be clearly defined in a widely accepted way. As he puts it, “Lots of people have jumped on the bandwagon.” However, without legally recognized definitions, spurious claims might serve to undermine operators that are truly achieving sustainable production.

Conclusion

Cod aquaculture relies heavily on functioning ecosystems. The feed supply depends on viable wild fish populations and the cage systems require clean coastal waters. Economic sustainability, in the form of consumer demand, and environmental sustainability are intrinsically linked. This study has demonstrated that a market for fish produced in an environmentally sensitive manner exists in the United Kingdom. The ease with which Johnson Seafarms sold its fish to retailers at premium prices adds weight to this argument and is an encouraging sign for the future of...
this incipient industry. Less promising is the failure of the company to sustain itself. The demise occurred for several reasons, including the high costs associated with farming a “new” species organically; the fact that, as the first operation of its kind, no model existed to build on; and the unfortunate timing of the global financial crisis. However, this demise does not automatically mean that environmentally sustainable aquaculture is destined to fail socially and economically. Well-managed future operations in a more favorable economic climate still have the potential to succeed.

With the industry represented by a sole producer, this investigation clearly has limited scope. However, a benchmark now exists from which to conduct further inquiries. Johnson Seafarms was tackling the serious obstacles to environmental sustainability, namely pollution, escapes, disease, and feed. If the methods and operational size that they demonstrated are used again in the future, organic cod farming may very well be able to show itself as environmentally, economically, and socially sustainable.

Given current sea-cage infrastructure and feed-production technologies, any expansion of the industry will inevitably result in increased pressure on the local environment and wider natural resource base in the form of fish for feed (at least until alternative feed sources can be more broadly commercialized). However, measured expansion can be sustainable as long as it replicates and seeks to improve upon Johnson Seafarms’ effective practices.

Nonetheless, organic cod farming cannot be viewed in isolation. Given the experiences of Johnson Seafarms, and the economic risks, any expansion of cod aquaculture is likely to include conventional, nonorganic methods that are likely to have a greater impact on the environment. Little is to be gained by the sustainability of only one section of the industry. Beyond defining organic and sustainable aquaculture standards, regulators have a duty to encourage best practices in all forms of aquaculture.

Acknowledgement

We would like to thank the eight aquaculture experts (Table 1) for their time and valuable input. We would also like to thank the two anonymous reviewers and the journal editor, Maurie Cohen, for their comments and suggestions on earlier versions of the manuscript.

References

Aarset, B., Standal, D., & Asche F. 2000. Cod Farming at the Intersection of Fisheries and Aquaculture. Working Paper No. 70/00. Bergen, Norway: Foundation for Research in Economics and Business Administration. http://bora.nih.no/bitstream/2330/1518/1/A70_00.pdf.

Adoff, G., Skjennum, F., & Engelsen, R. 2002. Experience and prospects of Norwegian cod farming. Bulletin of the Aquaculture Association of Canada 102(1):8–11.

Anderson, D., Gilibert, P., & Burkholder, J. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. Estuaries and Coasts 25(4):704–726.

Asche, F. & Tveterås, S. 2004. On the relationship between aquaculture and reduction fisheries. Journal of Agricultural Economics 55(2):245–265.

Bekkevold, D., Hansen, M., & Nielsen, E. 2006. Genetic impact of gadoid culture on wild fish populations: predictions, lessons from salmonids and possibilities for minimizing adverse effects. ICES Journal of Marine Science 63(2):198–208.

Black, E., Gowen, R., Rosenthal, H., Roth, E., Stechy, D., & Taylor, F. 1997. The costs of eutrophication from salmon farming: implications for policy—a comment. Journal of Environmental Management 50(1):105–109.

Brown, J., Minkoff, G., & Puwanerand, V. 2003. Larviculture of Atlantic cod (Gadus morhua): progress, protocols and problems. Aquaculture 227(1–4):357–372.

Carrell, S. 2008. World’s First Organic Cod Farm Sinks into Administration With £40 Million Debt. http://www.guardian.co.uk/environment/2008/mar/06/environment.ethicalfishing. December 1, 2008.

Cherry, D. 2009. Another one bites the dust. IntraFish February 20.

Chopin, T., Buschmann, A., Halling, C., Troell, M., Kautsky, N., Neori, A., Kraerner, G., Zertuche-González, J., Yarish, C., & Neefus, C. 2001. Integrating seaweeds into marine aquaculture systems: a key toward sustainability. Journal of Phycology 37(6):975–986.

Clover, C. 2008. World’s First Organic Cod Farm Closes. http://www.telegraph.co.uk/earth/earthcomment/charlesclover/339185/Worlds-first-organic-cod-farm-closes.html. December 1, 2008.

Commission of the European Communities (CEC). 2009. Communication from the Commission to the European Parliament and the Council: Building a Sustainable Future for Aquaculture. Brussels: CEC. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0162:FIN:EN:PDF.

Costa-Pierce, B. 2002. Ecology as the paradigm for the future of aquaculture. In B. Costa-Pierce (Ed.), Ecological Aquaculture: the Evolution of the Blue Revolution. pp. 339–372. Malden, MA: Blackwell.

Cromey, C., Nickell, T., Treasurer, J., Black, K., & Inall, M. 2009. Modelling the impact of cod (Gadus morhua L.) farming in the marine environment–CODMOD. Aquaculture 289(1–2):42–53.

Dahle, G., Jørstad, K., Rusas, H., & Otterå, H. 2006. Genetic characteristics of broodstock collected from four Norwegian coastal cod (Gadus morhua) populations. ICES Journal of Marine Science 63(2):209–215.

Dallimore, J. 2006. Consumers drive consensus on sustainability. Fish Farmer International 33(1):39.

de Vaus, D. 2002. Surveys in Social Research. 5th ed. New York: Routledge.

Ellis, R. 2003. The Empty Ocean. Washington, DC: Island Press.

Fish Farmer Magazine. 2006. New cod disease found in Norway. December 15:34.

Fish Farmer Magazine. 2008. Scottish Sea Farms and Hjaltland Buy No Catch Sea Farming Sites. http://www.fishfarmer-magazine.com/news/fullstory.php/aid/1587/Scottish_Sea_Farms_and_Hjaltland_buy_No_Catch_sea_farming_sites.html. December 1, 2008.

Fish Farmer Magazine. 2009. Scope for expansion of Irish organic salmon. http://www.fishfarmer-magazine.com/news/fullstory.php/aid/1817/Scope_for_expansion_of_Irish_organic_salmon.html. May 8, 2009.

Food and Agriculture Organization of the United Nations (FAO). 2000. The State of World Fisheries and Aquaculture 2000. Rome: FAO.

Food and Agriculture Organization of the United Nations (FAO). 2006. The State of World Fisheries and Aquaculture 2006. Rome: FAO.
Sustainability: Science, Practice, & Policy | http://ejournal.nbii.org Fall 2009 | Volume 5 | Issue 2

Food and Agriculture Organization of the United Nations (FAO). 2009. Fisheries Glossary. http://www.fao.org/fi/glossary/default.asp.

Folke, C., Kautsky, N., & Troell, M. 1994. The costs of eutrophication from salmon farming: implications for policy. Journal of Environmental Management 40(2):173–182.

Frankic, A. & Hershner, C. 2003. Sustainable aquaculture: developing the promise of aquaculture. Aquaculture International 11(6):517–530.

Goldburg, R., Elliott, M., & Naylor, R. 2001. Marine aquaculture in the United States. Washington, DC: Pew Oceans Commission.

Goldburg, R. & Naylor, R. 2004. Future seascape, fishing, and fish farming. Frontiers in Ecology and the Environment 3(1):21–28.

Gowen, R. 1994. Managing eutrophication associated with aquaculture development. Journal of Applied Ichthyology 10(4):242–257.

Hannesson, R. 2003. Aquaculture and fisheries. Marine Policy 27(2):78-79.

Hepburn, J. 2004. Organic aquaculture—the UK experience. INFORM FISH International 4:14–18.

Highlands & Islands Enterprise. 2002. Scottish Executive Review of the Aquaculture Industry in Scotland. http://www.scotland.gov.uk/Resource/Doc/46951/0024232.pdf. December 1, 2008.

Horwood, J., O’Brien, C., & Darby, C. 2006. North Sea cod recovery? ICES Journal of Marine Science 63(1):96–101.

International Council for the Exploration of the Sea (ICES). 2007. ICES Advice 2007, Book 6: North Sea. Report of the ICES Advisory Committee on Fishery Management, Advisory Committee on the Marine Environment and Advisory Committee on Ecosystems. Copenhagen: ICES. http://www.ices.dk/products/icesadvice2007/ICES%20ADVICE%202007%20Book%206.pdf.

Jacquet, J. & Pauly, D. 2007. The rise of seafood awareness campaigns in an era of collapsing fisheries. Marine Policy 31(3):308–313.

Jorstad, K. 2004. Genetic studies in marine stock enhancement in Norway. In K. Leber, S. Kitada, H. Blankenship, & T. Svaand (Eds.), Proceedings of Second International Symposium on Stock Enhancement and Sea Ranching. pp. 339–352. Malden, MA: Blackwell Science.

Kaiser, M. & Stearn, S. 2002. Uncertainties and values in European aquaculture: communication, management and policy issues in times of “changing public perceptions.” Aquaculture International 10(6):469–490.

Kapucinski, A. & Hallereman, E. 1991. Implications of introduction of transgenic fish into natural ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 48(1):99–107.

Kjesbu, O., Taranger, G., & Trippel, E. 2006. Gadoid mariculture: development and future challenges. Introduction. ICES Journal of Marine Science 63(2):187–191.

Lee, D. & Connelly, J. 2006. Global aquaculture alliance on best aquaculture practices: an industry prepares for sustainable growth. Sustainable Development Law & Policy 7(1):10–62.

MacGarvin, M. 2000. Scotland’s Secret? Aquaculture, Nutrient Pollution Eutrophication and Toxic Blooms. Modus Vivendi for WWF. Glenlivet, Scotland: WWF Scotland. http://www.wwf.org.uk/library/pdf/secret.pdf.

Mignaud, H. 2007. Development of new management strategies for cod mariculture. Aquaculture News 33:12–13.

Myers, R., Hutchings, J., & Barrowman, N. 1997. Why do fish stocks collapse? The example of cod in Atlantic Canada. Ecological Applications 7(1):91–106.

Naylor, R., Goldburg, R., Mooney, H., Beveridge, M., Clay, J., Folke, C., Kautsky, N., Lubchenco, J., Primavera, J., & Williams, M. 1998. Nature’s subsidies to shrimp and salmon farming. Science 282(5390):883–884.

Naylor, R., Goldburg, R., Primavera, J., Kautsky, N., Beveridge, M., Clay, J., Folke, C., Lubchenco, J., Mooney, H., & Troell, M. 2000. Effect of aquaculture on world fish supplies. Nature 405(6790):1017-1024.

Naylor, R., Eagle, J., & Smith, W. 2003. Salmon aquaculture in the Pacific Northwest: a global industry with local impacts. Environment 45(8):18–39.

Naylor, R. & Burke, M. 2005. Aquaculture and ocean resources: raising tigers of the sea. Annual Review of Environment and Resources 30:185–218.

Naylor, R., Hindar, K., Fleming, I., Goldburg, R., Williams, S., Volpe, J., Whoriskey, F., Eagle, J., Kelso, D., & Mangel, M. 2005. Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. BioScience 55(5):427–437.

Neori, A., Chopin, T., Troell, M., Buschmann, A., Kraemer, G., Halling, C., Shipgel, M., & Yarish, C. 2004. Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. Aquaculture 231(1–4):361–391.

Organic Food Federation (OFF). 2005. Aquaculture Standards. Book 7: Gaidoids. http://www.orgfoodfed.com/Our%20Standards.htm. May 8, 2009.

Olsen, A.-B., Mikalsen, J., & Colquhoun, D. 2006. New disease identified in Norway’s farmed cod. Aquaculture Health International 4:7.

Opstad, I., Suontama, J., Langmyhr, E., & Olsen, R. 2006. Growth, survival, and development of Atlantic cod (Gadus morhua L.) weaned onto diets containing various sources of marine protein. ICES Journal of Marine Science 63(2):320–325.

Österblom, H., Hansson, S., Larsson, U., Hjerne, O., Wulff, F., Elmgren, R., & Folke, C. 2007. Human-induced trophic cascades and ecological regime shifts in the Baltic Sea. Ecosystems 10(6):877–889.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T., Samaula, U., Walters, C., Watson, R., & Zeller, D. 2002. Towards sustainability in world fisheries. Nature 418(6898):689–695.

Pauly, D. 2006. Unsustainable marine fisheries. Sustainable Development Law & Policy 7(1):10–12.

Poullier, S. 2007. “The autumn” of organic cod farming, by expert. Daily Mail February 15:12.

Powell, K. 2003. Eat your veg. Nature 426(6965):378–379.

Rawlinson, P. & Forster, A. 2000. The Economics of Recirculation Aquaculture. International Institute of Fisheries Economics and Trade Conference. July 10–14, Oregon State University, IIDET. http://oregonstate.edu/dept/IIFET/2000/papers/rawlinson.pdf.

Reuters. 2008. Iceland Bank Koftaing Files for US Bankruptcy. http://www.reuters.com/article/usDollarRpt/USN105134620081201/March 1, 2009.

Ritchie, J. & Spencer, L. 1994. Qualitative data analysis for applied policy research. In A. Bryman & R. Burgess (Eds.), Analyzing Qualitative Data. pp. 173–194. New York: Routledge.

Rosenlund, G. & Skretting, M. 2006. Worldwide status and perspective on gatoid culture. ICES Journal of Marine Science 63(2):194–197.

Samuelsen, O., Nerland, A., Jorgensen, T., Schroder, M., Svendsen, T., & Bergh, O. 2006. Viral and bacterial diseases of Atlantic cod (Gadus morhua), their prophylaxis and treatment: a review. Diseases of Aquatic Organisms 71(3):239–254.

Scottish Executive. 2006. Scottish Fish Farms Annual Production Survey. 2005: Aberdeen: Fisheries Research Service. http://www.marlab.ac.uk/FRS.Web/Uploads/Documents/survey2005.pdf.

Soto, D., Jara, F., & Moreno, C. 2001. Escaped salmon in the inner seas, southern Chile: facing ecological and social conflicts. Ecological Applications 11(6):1750–1762.

Standal, D. & Bouwer Ume, I. 2007. Can cod farming affect cod fishing? A system evaluation of sustainability. Marine Policy 31(4):527–534.

Tilseth, S. 1990. New marine fish species for cold-water farming. Aquaculture 85(1–4):235–245.

Troell, M., Halling, C., Neori, A., Chopin, T., Buschmann, A., Kautsky, N., & Yarish, C. 2003. Integrated mariculture: asking the right questions. Aquaculture 226(1–4):69–90.

Walden, J. 2000. The Atlantic cod: the potential for farming in Shetland. Fisheries Information Note 3:January.

Wurts, W. 2000. Sustainable aquaculture in the twenty-first century. Reviews in Fisheries Science 8(2):141–150.