INCREASING THE SPAWNING BIOMASS OF NORTHERN ATLANTIC COD, *Gadus morhua*, THROUGH THE RELEASE OF MATURE FARMED FISH

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Increasing the Spawning Biomass of Northern Atlantic Cod, *Gadus morhua*, Through the Release of Mature Farmed Fish

by

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INTRODUCTION

The stock abundance of the northern Atlantic cod, *Gadus morhua*, is presently at a historic low level. In the mid 1960's the spawning stock biomass (historically assumed to be fish aged 7+ for statistical purposes) exceeded a million metric tons (Lear and Parsons 1993), but overfishing eventually caused the cod stock to collapse. Consequently a moratorium on domestic fishing was established by the Canadian Federal Government in 1992 (Hutchings and Myers 1994a). By 1992 the total stock size (fish aged 3+) had dropped to 125,000 mt (Bishop *et al.* 1993). In 1993 the spawning biomass of the northern cod stock was estimated at 22,000 mt (Lear and Parsons 1993). Age at 50% maturity since the late 1980's has shown a trend toward younger (4-5 yrs old) fish (Taggart *et al.* 1994). The present spawning biomass is composed of relatively young cod.

The intent of the current moratorium on fishing cod in Atlantic Canada is to allow the cod stocks to recover. However a recovery of the northern cod stock has not been detected (Fisheries Resource Conservation Council 1996). One management option is intervention to increase the spawning biomass (Wroblewski *et al.* 1996). It may be possible to increase the numbers of mature cod through release of farmed fish and thus enhance recruitment to the northern Atlantic cod population (Working Group on Cod Enhancement 1994). This could be achieved operationally by capturing young cod in traps, holding them in pens, feeding them to satiation throughout the growth season, and releasing them back into the wild. Cod farmers in Newfoundland have demonstrated that fish taken from the wild, held in sea cages, and fed a natural diet, can double in weight and grow several centimeters in length over the summer months (Fisher 1988). Late in the growth season most weight gain appears as gonadal tissue rather than somatic tissue (Lee 1988). Some juvenile cod may reach sexual maturity one year earlier in farms than in the wild (Waiwood 1982; Karlsen *et al.* 1995). Once released, farm fish could augment the spawning biomass of cod resident in Newfoundland bays (Wroblewski *et al.* 1994; Ruzzante *et al.* 1996; Wroblewski *et al.* 1996). There is generally a positive relationship between northern cod spawning stock biomass and subsequent recruitment (Myers and Barrowman 1996).

The method of stock enhancement being investigated in this study, termed "grow-out and release" (Working Group on Cod Enhancement 1994), is novel in terms of traditional stock enhancement programs. Traditionally, fish are raised in a hatchery from the egg stage and then released into the wild at various life-history stages (depending on the species), but generally as juveniles (Richards and Edwards 1986). Hatchery based stocking programs have met with much criticism over the years, especially regarding their effectiveness at increasing numbers of fish, and the fitness of fish after release (Howell 1994; White *et al.* 1995). There have been numerous accounts of behavioral, genetic, physiological, and morphological anomalies associated with hatchery released fish (see reviews by Blaxter 1975; Marnell 1986; Heggberget *et al.* 1993; Washington and Koziol 1993; White *et al.* 1995); hence the need for other stock enhancement strategies (eg. Blankenship and Leber 1995). The grow-out and release method involves growth advancement of wild fish, rather than production of eggs and juveniles in a hatchery. Using wild fish avoids the genetic manipulation associated with hatchery broodstock. However there may be behavioral effects of captivity stemming from holding and feeding.

There is information available on the fecundity of cod cultured from the egg stage (eg. Kjesbu 1989; Kjesbu *et al.* 1991), but published information on the potential fecundity of wild cod fed in captivity is limited. Chambers and Waiwood (1996) report the fecundity of captive cod as the number of eggs released, rather than quantity of eggs in the ovary prior to spawning (potential fecundity). They also do not report the feeding level of their experimental fish.

The first objective of this study (chapter 1) was to determine if wild northern cod would have significant gains in potential fecundity, after being fed to near satiation every 2-3 days over several growing seasons. I hypothesized that farmed cod would have significantly greater fecundity than wild cod of the same length, weight, or age. A second objective (chapter 2) was to determine if cod, held captive over several growing seasons in nearshore waters, would have a similar spawning period as wild cod. I hypothesized that holding cod in sub-zero waters over the winter would delay their spawning period relative to wild cod which overwinter in deeper, warmer waters. Related to the second objective, I also examined the viability of eggs and larvae of farmed cod. A third objective (chapter 3) was to test the hypothesis that captive cod would become domesticated by feeding (ie. the cod would become tame and accustomed to their new home). Therefore once released, the time to leave the farm site would be significantly longer for captive cod than wild cod (released at the same time and place). As part of this third objective, I also wished to determine if captivity had any effects on fishing mortality of cod after their release back into the ocean.

CHAPTER 1

Fecundity of farmed northern Atlantic cod

For cod enhancement by "grow-out and release" to be feasible there must be a significant gain in the fecundity of farmed cod over wild cod. Hence, a study was conducted to compare fecundities of both groups. This involved determining the fecundities of fish with a known history from a cod farm, and comparing them to published fecundity data of wild cod. Condition factors, as an indication of nutritional well-being, were also compared between farmed and wild fish (sampled at the same time). I hypothesized that the fecundity of farmed cod would be significantly greater than the fecundity of same size (or age) wild cod.

1.1 Materials and Methods

The study was conducted in the Random Island region of Trinity Bay (Figure 1.1). During June 1992 several thousand juvenile and adult cod were captured in a cod trap near East Random Head, Trinity Bay and transported by boat (Fisher 1988) to a sea cage in Gooseberry Cove (Figure 1.2). The sea cage measured approximately 9 x 11 x 5 m deep and was moored in water of 18 m depth. The number of cod in the cage declined over time as some fish were harvested each fall. There was an annual loss of approximately 5% of the fish due to natural mortality (eg. predation by sea otters). On 17 April, 1995 there were approximately 1000 cod remaining in the cage. By 4 April 1996 there were only about 300 cod in the cage. These were the fish used in the present study.

The fish were maintained in the cage for four years and fed natural prey (fresh/frozen: capelin, herring, or squid based on local availability) through the growth season (May to October). The fish were fed to satiation every 2-3 days. Feeding ceased with the onset of cold water temperatures in the late fall (October to November), as expected (Waiwood *et al.* 1991).

Landfast ice covered the site annually from early February until mid-late April. During the winter months the fish survived in sub-zero water by producing antifreeze glycoproteins (Fletcher *et al.* 1997). Temperature and salinity profiles adjacent to the cage were taken periodically during the winter of 1993-94 using a Seabird Electronics Inc. Seacat SBE 19-03 (see Fletcher *et al.* 1997). Salinity profiles indicated a salinity of approximately 32 ppt below a depth of 1 m. Freshwater runoff lowered the salinities of the upper meter occasionally below 15 ppt. Temperature at 5 m depth was recorded near continuously from 17 April 1995 to 4 April 1996 (Figure 1.3) using a Vemco Ltd. Sealog-TD, attached to the bottom of the sea cage.

Morphometric measurements and condition factors of farmed and wild cod

On 17 April 1995 twelve farmed fish were sacrificed for health evaluation. Analyses were performed at two pathology laboratories: Fisheries and Marine Institute, Memorial University of Newfoundland, and the Atlantic Veterinary College, University of Prince Edward Island.

During 17-18 April 1995, 244 farmed fish were randomly sampled from the cage for fork length (L) (nearest 0.5 cm), whole wet weight (W) (± 10 g), and presence of the gill parasite *Lernaeocera branchialis* (Appendix A). For comparison, 267 wild cod caught in Smith Sound, Trinity Bay (Figure 1.2) on 24-25 April 1995 were sampled for fork length (nearest cm), whole wet weight (± 5 g) and external parasites (Appendix B). The fish were caught using an otter trawl (# 36 Yankee) at a depth of 154 meters by the C.R.V. *Shamook*. The duration of the tow was five minutes. Sagittal otoliths were removed from 37 farmed and 50 wild cod for aging by personnel at Science Branch, DFO, St. John's (Appendix A, B).

Farmed and wild fish were also sampled in September, 1995 for an indication of post-spawning condition. On 7 September 1995, 45 farmed fish were randomly sampled for fork length (to nearest 0.5 cm), whole (W) and gutted (W_g) weights (± 10 g), and liver weight (± 10 g) (Appendix C). On 26 September 1995, 49 wild fish were randomly sampled from a sentinel fishery (Davis and Jarvis 1996). The fish were caught with gillnets (5.5 inch mesh) set in Smith Sound (Figure 1.2). Measurements were made in the same manner as for the farmed fish (Appendix D). The presence of *L. branchialis* was also noted for each group. All fish sampled in September were aged using sagittal otoliths.

On 4 April 1996, 15 female farmed cod were sampled prior to spawning. Measurements of whole body wet weight and gutted weight (± 20 g), gill, liver and ovary weights (± 1 g), and fork length (to nearest cm) were taken (Appendix E). The presence of external and internal parasites was noted. Sagittal otoliths were removed for aging. Spawning checks between growth rings were noted when present (May 1960). Fulton's condition factor (K) was calculated as $K = W / L^3 \times 100$. K_g uses gutted wet body weight,

W_g, rather than W. The gonado-somatic index (GSI) was calculated as GSI = (gonad wet weight / W) x 100. The hepato-somatic index (HSI) was calculated as HSI = (liver wet weight / W) x 100.

Fecundity analysis of farmed cod

Sampling of the 15 female farmed cod on 4 April 1996 was conducted before spawning to avoid loss of hydrated eggs. Gonads were collected late enough in the annual reproductive cycle so that vitellogenic (present generation) and previtellogenic (<250 µm)(second generation) oocytes could be separated by size (May 1967; Kjesbu *et al.* 1990). Previtellogenic oocytes were not included in fecundity estimates, since they would not be released until the following spawning season. Following Kjesbu *et al.* (1991), potential fecundity was defined as the number of vitellogenic oocytes in an ovary prior to spawning.

The fifteen females sampled on 4 April 1996 were identified by cannulation for fecundity analysis, whereby a plastic tube (2.0 mm inside diameter) was inserted into the genital pore and a small number of oocytes were sampled via suction. If the biopsy showed no hydrated oocytes, the female was selected for subsequent analysis. Later examination of the ovaries revealed that two of these fish had commenced hydration, so their examination was not continued beyond morphometric measurements and condition factors.

The potential fecundity of the remaining 13 fish was determined using the gravimetric wet weight method (Bagenal 1978; Kjesbu 1989). This method gave values consistent with two other methods for measuring fecundity (Wroblewski *et al.* 1997); hence, it was used for this study (easiest of the three methods). Three subsamples of ovarian tissue (each 100-300 mg) were taken from the middle of the right ovary (Table 1.1). Kjesbu (1988) found sampling from the centre of the ovary as reliable as sampling from other locations. This homogeneous nature occurs since the germinal epithelium is so highly convoluted that it completely fills the ovary (Beverton and Holt 1957). Vitellogenic oocytes in each subsample were counted using a dissecting microscope with an ocular micrometer. Very few oocytes smaller than 250 μm were observed and consequently only oocytes > 250 μm were counted. Subsample counts were averaged. Potential fecundity was then calculated using the wet weight of the ovary.

The fecundities of Gooseberry Cove farmed cod were then compared to fecundity data of wild cod from Labrador and eastern Newfoundland (May 1967) and from Trinity Bay (Pinhorn 1984). Our data was also compared to Norwegian cod cultured from the egg (Kjesbu 1989; Kjesbu *et al.* 1991).

Statistical analysis

All equations were derived from regression analyses, and the weight-length relationships for farmed and wild cod were compared using ANCOVA (general linear model, Minitab, 1989), with type I error rate $\alpha = 0.05$, following the procedures described in Sokal and Rohlf (1995).

1.2 Results

Feeding captive Trinity Bay cod for four growth seasons in sea cages, to near satiation levels with natural feed (natural feed is considered a high growth diet; see Jobling 1988), resulted in the weight-length relationship shown in Figure 1.4, expressed by the equation $W = 0.0302\ L^{2.79}$ ($r^2 = 0.69$, $p < 0.0005$). Wild Trinity Bay cod sampled in Smith Sound on 25 April 1995 had a lower weight at length relationship, expressed by $W = 0.0115\ L^{2.93}$ ($r^2 = 0.91$, $p < 0.0005$) (Figure 1.4). The data was log-transformed for a straight line relationship according to:

$$W = a\ L^b$$

$$\log W = \log a + b \log L$$

and an ANCOVA was performed to determine if the two groups of fish were significantly different. The slopes of the log-transformed data were not significantly different ($F_{1,505} = 1.32$, $p = 0.252$) so a revised model was used without the interaction term. The means for the two groups and hence the intercepts differed significantly ($F_{1,506} = 728.87$, $p < 0.0005$). The revised model was:

$$W = a\ L^{2.89}$$

$$\log W = \log a' + 2.89 \log L$$

$$\text{where: } a'_1 = -1.72125 \text{ (the intercept for farmed cod)}$$

$$a'_2 = -1.88606 \text{ (the intercept for wild cod)}$$

$$\text{and: } W = 0.019\ L^{2.89} \text{ (for farmed)}$$

$$W = 0.013\ L^{2.89} \text{ (for wild)}$$

This clearly indicates that farmed cod were heavier (approx. 1-2 kg) over the length range tested. The residuals were not associated with the fitted values; therefore the model is acceptable. Also, the residuals plotted against the normal scores was a straight line.

Therefore the p-values from the ANOVA tables could be trusted.

Figure 1.5 shows that near the end of the fourth growth season (September 1995), farmed cod were almost twice the weight of wild cod of the same age. The weight-age relationship for 45 Trinity Bay farmed cod was $W_g = 758\ A - 1549$ ($r^2 = 0.30$, $p < 0.0005$), and for 49 wild cod was $W_g = 411\ A - 464$ ($r^2 = 0.38$, $p < 0.0005$).

The farmed cod were in good health as necropsy reports from both pathology laboratories on the fish sampled on 17 April 1995 confirmed the absence of infectious organisms. The farmed fish had a higher condition (K) than wild cod at the times of sampling in April ($F_{1, 532} = 101.31$, $p < 0.0005$), and September ($F_{1, 96} = 8.28$, $p < 0.005$), 1995 (Table 1.2). As well, in September the K_g for farmed cod was greater than that computed for wild cod ($F_{1, 96} = 4.93$, $p = 0.029$) (Table 1.2). A higher HSI also revealed the farmed fish had larger livers in the post-spawning condition during September ($F_{1, 96} = 52.97$, $p < 0.0005$) (Table 1.2).

Four percent of 242 farmed cod examined on 17-18 April 1995 had one or more gill parasites *(L. branchialis)* (Appendix A), while 11% of 267 wild cod from Smith Sound examined on 24 April 1995 were infected (Appendix B). *L. branchialis* may cause slow growth of Atlantic cod (Kahn *et al.* 1990). A few *Anisakis* sp. were found on the livers of farmed cod sampled for fecundity measurements on 4 April 1996; however, these larval nematodes were not observed in Gooseberry Cove farmed fish before this date. There were no *L. branchialis* present on the 4 April 1996 samples. Spawning checks on otoliths were clearly observed in 4 out of 15 farmed cod examined on 4 April 1996.

Multiple spawning was evident in 3 fish, with first spawning check at age 4 in one fish and at age 5 for the others.

Potential fecundity of farmed cod

The potential fecundity of the farmed Trinity Bay cod was a function of the whole wet body weight of the fish, expressed as $F = 1.19 \times 10^3 W - 6.0 \times 10^5$ ($r^2 = 0.29$, $p = 0.035$). The potential fecundity of the farmed cod plotted against the gutted-gilled weight of the fish (Figure 1.6) was $F = 1.43 \times 10^3 W_{gg} + 4.3 \times 10^5$ ($r^2 = 0.23$, $p = 0.058$) where W_{gg} is the gutted-gilled weight. Pinhorn (1984) did not plot fecundity against weight for wild Trinity Bay cod, so the relationship for 21 northern Grand Bank cod, $F = 4.1 \times 10^2 W_{gg} + 4.2 \times 10^5$ ($r^2 = 0.52$, $p < 0.01$) (May 1967) , was used for comparison in Figure 1.6.

The potential fecundity of the farmed Trinity Bay cod as a function of length (Figure 1.7) was not statistically significant (i.e. the slope of the relationship was not different from zero) ($r^2 = 0.06$, $p = 0.199$). Pinhorn (1984) found a relationship between fecundity of 78 wild Trinity Bay cod and length, $F = 1.778 L^{3.13}$ ($r^2 = 0.61$, $p = 0.01$) (Figure 1.7). Comparing his data to that of May (1967), Pinhorn (1984) found no significant difference in fecundity-length relationships between Trinity Bay cod and cod from the eastern Newfoundland continental shelf.

The fecundity of farmed Trinity Bay cod could not be related to the age of the fish (Figure 1.8). Pinhorn (1984) found a relationship between age and fecundity for 78 wild Trinity Bay cod, and his equation $F = 21878 A^{1.91}$ ($r^2 = 0.52$, $p = 0.01$) where A is age has been plotted in Figure 1.8.

Relative fecundity of farmed cod

Following Kjesbu and Holm (1994), the relative fecundities of the farmed cod were calculated as F/S were F is the potential fecundity and S is the somatic weight (whole body wet weight - wet weight of ovary). Moderately fed (2-3% body weight every 2-3 days) farmed Placentia Bay cod (Wroblewski *et al.* 1997) were compared to the farmed cod of this study (fed to satiation every 2-3 days). The mean relative fecundity (± sd) of farmed Placentia Bay cod was 916 (±401, n = 35) oocytes per gram of somatic weight (Figure 1.9). The mean relative fecundity (± sd) for farmed Trinity Bay cod was 1187 (±249, n = 13). Since the variances of the two groups were unequal, a Smith-Satterthwaite one-tailed t-test (Devore 1987, pg. 339) was used to determine whether the farmed cod in this study had a higher relative fecundity than the farmed Placentia Bay cod. The farmed Trinity Bay cod had significantly more oocytes per gram somatic weight ($t = 2.56$, $p = 0.015$, $df = 36$).

The relative fecundity achieved by farming at Gooseberry Cove was nearly identical to that of cod cultured under a high feeding regime in a laboratory experiment (Kjesbu and Holm 1994, Fig. 1). For comparison, the mean relative fecundity (± sd) for wild cod from the Gulf of St. Lawrence (Buzeta and Waiwood 1982) is 409.8 (± 174, n = 32), shown in Figure 1.9.

1.3 Discussion

The farmed cod fecundity data of this study was compared to wild cod fecundity reported by May (1967) and Pinhorn (1984). It was assumed that fecundities of

Newfoundland cod have not changed since these original studies. Kjesbu (1989) found that fecundities of coastal Norwegian cod in 1986-1987 were not significantly different from that reported in 1959. However, during the collapse of the cod fishery off Newfoundland's east coast, reduced fecundities within the spawning biomass due to poor condition (reduced food availability) may have occurred. There may also have been a multi-year trend in reduced fecundity leading up to the collapse of the fishery.

Wild cod, held captive over four growth seasons, significantly increase their vitellogenic oocyte production, and hence potential fecundity, compared to free-living cod. The potential fecundity of farmed fish is a function of weight of the fish, as it is in the wild (May 1967; Pinhorn 1984). Weight-at-length and weight-at-age of the farmed cod were considerably higher than observed in wild cod, indicating an advanced fecundity at length (age). Moreover, the relative fecundity (potential fecundity per unit somatic weight) of farmed cod was higher than in the wild, suggesting that wild cod do not always feed to satiation or they have different energy expenditures from farmed cod. In comparison to farmed cod from Placentia Bay the higher relative fecundity of the farmed Trinity Bay cod (Figure 1.9) was also related to feeding levels. The field results were consistent with relative fecundities achieved in cod raised in the laboratory. First time spawners raised in the laboratory by Kjesbu and Holm (1994) had similar relative fecundities to the repeat spawners of this study. Thus, it appears that one growth season in captivity may be sufficient for wild cod to maximize their relative fecundity during the subsequent spawning period.

Recruitment potential represented by the weight of farmed cod released into Newfoundland bays would be underestimated if one simply used fecundity-weight relationships based on wild cod (eg. May 1967; Pinhorn 1984). My data indicate that feeding cod to satiation over four growth seasons resulted in greatly advanced fecundity. Cod from Trinity Bay farmed over four growth seasons and fed to satiation obtained fecundities 2-4 times that of their wild counterparts (Figures 1.6, 1.7). Good condition, as a result of satiated feeding, of the farmed cod after spawning likely resulted in high fecundities the following year. Kjesbu *et al.* (1991) found that cod with high condition factors produce more previtellogenic oocytes and used a larger fraction during vitellogenesis. Few oocytes, < 250 μm, were observed in the ovarian samples of the farmed cod indicating that most oocytes were maturing, or that the ovarian tissue examined undersampled the lamellae containing small oocytes.

Whether released farmed cod will continue to produce more eggs, compared to their wild counterparts, in subsequent years after release has yet to be determined. Kjesbu *et al.* (1996) suggested that for cod raised in the laboratory, high reproductive investment in one season negatively affected egg production and growth in the following season. The results of this study demonstrate that in the post-spawning condition, farmed cod have a relatively high condition factor (K) and liver index (HSI) (see Table 1.2). Even if egg production of farmed cod is reduced in the second season after release, they may still have a greater fecundity than wild cod.

Table 1.1: Fecundity data from Atlantic cod, *Gadus morhua*, sampled at the Gooseberry Cove fish farm on April 4, 1996. The ovary sample number corresponds to the fish number in Appendix E. Fish 5 and 12 had hydrated oocytes. Three sub-samples (denoted a, b and c) were taken from each ovary. Fec. is the potential fecundity.

sample (#)	sample wt. (g)	sample oocytes (#)	Fec. (10^6)	sample (#)	sample wt. (g)	sample oocytes (#)	Fec. (10^6)
1a	0.154	2825	7.67	9a	0.137	1316	5.80
1b	0.208	3706	7.45	9b	0.149	1436	5.82
1c	0.174	3167	7.61	9c	0.115	1064	5.59
2a	0.119	2062	7.21	10a	0.169	1075	3.32
2b	0.126	2025	6.69	10b	0.175	1238	3.69
2c	0.135	2661	8.20	10c	0.160	1169	3.81
3a	0.156	2540	8.11	11a	0.158	2285	5.03
3b	0.267	4266	7.96	11b	0.129	2082	5.62
3c	0.189	3093	8.15	11c	0.146	1724	4.12
4a	0.218	2466	6.76	12a	0.167	429	2.92
4b	0.146	1795	7.35	12b	0.128	314	2.79
4c	0.219	2579	7.04	12c	0.241	625	2.95
5a	0.241	488	2.54	13a	0.107	1170	3.96
5b	0.299	480	2.01	13b	0.118	1353	4.15
5c	0.161	320	2.49	13c	0.251	2753	3.97
6a	0.160	2269	4.28	14a	0.153	1824	5.75
6b	0.151	2065	4.13	14b	0.197	2512	6.15
6c	0.143	2031	4.29	14c	0.117	1481	6.10
7a	0.133	1208	4.27	15a	0.234	1831	5.57
7b	0.133	1280	4.52	15b	0.188	1401	5.31
7c	0.150	1381	4.33	15c	0.259	2006	5.52
8a	0.136	1072	4.40				
8b	0.124	942	4.24				
8c	0.111	801	4.03				

Table 1.2: Mean (± 1 s.d.) condition factors for farmed and wild Atlantic cod, *Gadus morhua*, from Trinity Bay, NF. K = Fulton's condition factor. Kg = Fulton's condition factor using gutted weight. HSI = hepato-somatic index. GSI = gonado-somatic index.

	Date	n	K	K_g	HSI (%)	GSI (%)
farmed	17 Apr 95	242	1.22 (0.16)	--	--	--
wild	24 Apr 95	267	0.85 (0.10)	--	--	--
farmed	7 Sept 95	45	1.23 (0.12)	1.00 (0.1)	12 (1.68)	--
wild	26 Sept 95	49	0.98 (0.12)	0.82 (0.1)	7.12 (1.82)	--
farmed	4 Apr 96	15	1.27 (0.09)	0.90 (0.07)	12.3 (1.67)	10.59 (3.95)

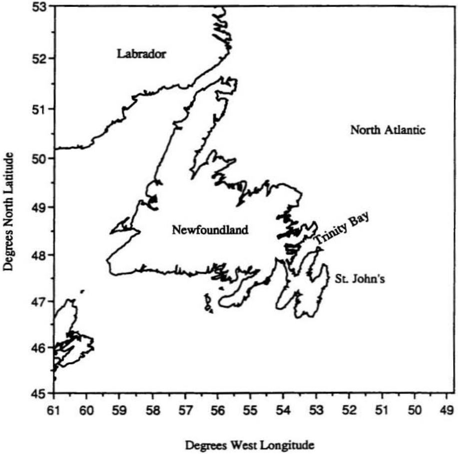

Figure 1.1: A map of Newfoundland showing Trinity Bay.

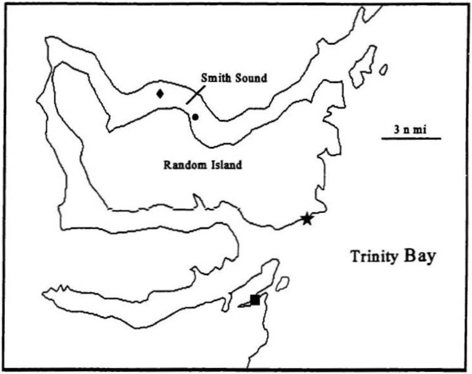

Figure 1.2: The Random Island region in western Trinity Bay, with locations of Gooseberry Cove cod farm (square), East Random Head (star) where the farmed cod were originally trapped during June 1992, and site in Smith Sound (diamond) where wild cod were captured in April 1995 and transported to the farm for sonic tagging and release. Circle denotes location of wild cod sampled in September 1995.

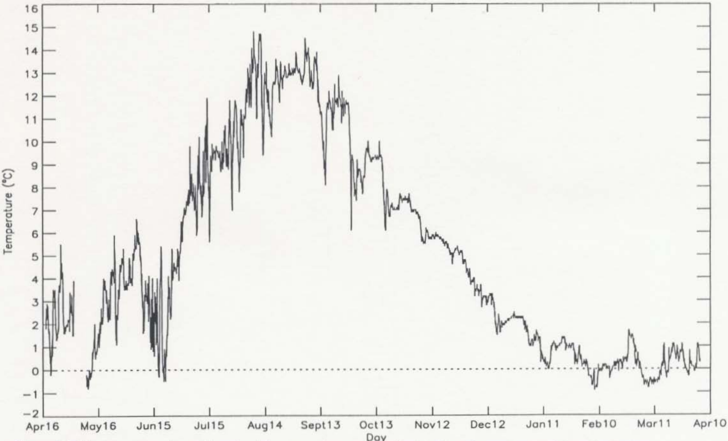

Figure 1.3: Temperatures taken at 5 m depth (near continuous recording) at Gooseberry Cove cod farm site during 17 April 1995 - 4 April 1996.

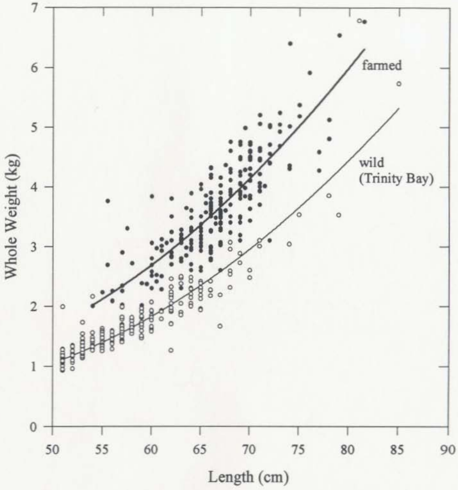

Figure 1.4: Whole weight (kg) versus length (cm) for farmed Trinity Bay cod (n = 242) sampled on 17 April 1995 compared to wild Trinity Bay cod (n = 267) sampled from Smith Sound on 24 April 1995.

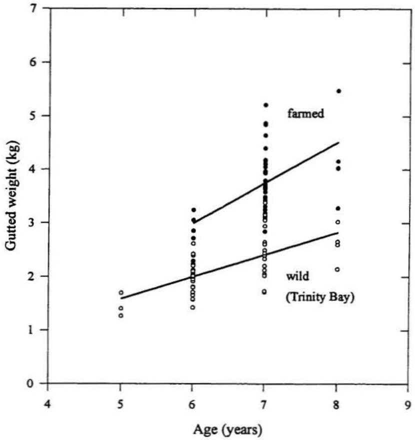

Figure 1.5: Gutted weight (kg) versus age (years) for farmed Trinity Bay cod (n = 45) sampled on 7 September 1995 compared to wild Trinity Bay cod (n = 49) sampled from Smith Sound on 26 September 1995.

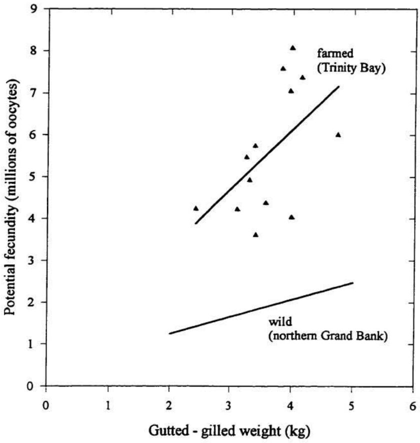

Figure 1.6: Potential fecundity (millions of oocytes) versus gutted-gilled weight (kg) for farmed Trinity Bay cod (n = 13) sampled on 4 April 1996 compared to wild northern Grand Bank cod (n = 21) reported by May (1967).

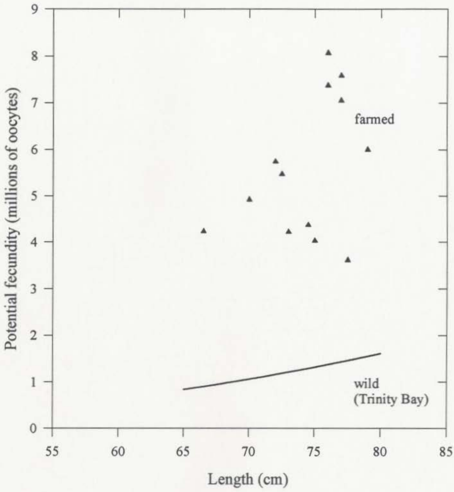

Figure 1.7: Potential fecundity (millions of oocytes) versus length (cm) for farmed Trinity Bay cod (n = 13) sampled on 4 April 1996 compared to wild Trinity Bay cod (n = 78) reported by Pinhorn (1984).

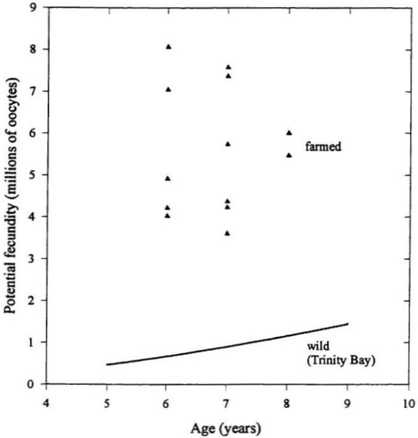

Figure 1.8: Potential fecundity (millions of oocytes) versus age (years) for farmed Trinity Bay cod (n = 13) sampled on 4 April 1996 compared to wild Trinity Bay cod (n = 78) reported by Pinhorn (1984).

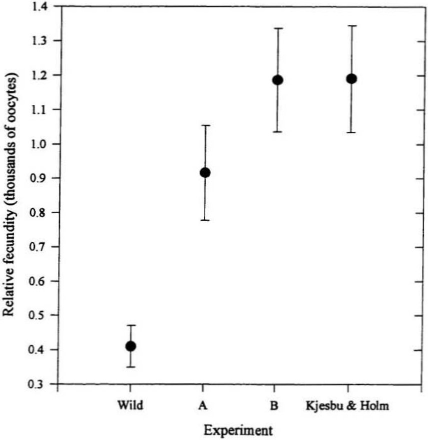

Figure 1.9: Relative fecundity (thousands of oocytes) for farmed cod (A = farmed Placentia Bay cod, see Wroblewski *et al.* 1997. B = farmed Trinity Bay cod, this study), wild cod (Buzeta & Waiwood 1982), and laboratory cultured cod (Kjesbu & Holm 1994). Vertical lines are 95% confidence limits.

CHAPTER 2

Spawning behavior and egg viability of farmed cod

In April, 1995 female fish were randomly selected from both the cod farm in Gooseberry Cove and from cod caught in Smith Sound, Trinity Bay to compare their state of gonadal development. A spawning cage was installed at the farm in May, 1995 to determine the spawning period of the farmed cod, and to investigate the viability of their eggs. Eggs were collected from the spawning cage periodically and transported to the Marine Science Research Laboratory (MSRL) in Logy Bay, Newfoundland where egg quality analyses were conducted. The rationale for these tasks was to test the hypothesis that farmed cod spawn and produce viable offspring.

2.1 Materials and Methods

Oocyte sampling of experimental and wild cod

On April 17-18, 1995, 100 randomly selected farmed fish were cannulated to determine sex and collect gonadal biopsies (see Chapter 1 for description of technique). Ovarian tissue collected from females was preserved in vials containing 1% buffered formalin for 6-12 months before being examined. Fork length (to the nearest 0.5 cm) and whole weight (± 10 g) was recorded for each fish. Of the 100 fish biopsied, 75 were female (Appendix A). Examination of the ovarian tissue involved measuring the diameter of 100 randomly selected oocytes from each fish using a dissecting microscope with an ocular micrometer (to the nearest 0.1 mm), and then pooling the results for the entire group (Appendix F). Kjesbu (1994) demonstrated that measuring two axes per oocyte (long and short diameter) was more precise than measuring one axis, but the difference was insignificant when comparing groups rather than individuals. Hence only one diameter per oocyte was measured.

On April 24-25, 1995, 100 wild fish were randomly selected from cod caught in Smith Sound. The fish were caught by the C.R.V. *Shamook* using an otter trawl (see Chapter 1). Fork length (to the nearest cm) and whole weight (± 5 g) was recorded for each fish. Of the 100 fish sampled, 51 were female (Appendix B). Ovarian biopsies and oocyte measurements were performed in the same manner described for the farmed cod above (Appendix G).

Spawning period and egg collection

To facilitate the collection of fertilized eggs at the farm a spawning cage was constructed and installed adjacent to the farm. The spawning cage measured 3m x 3m x 4m deep and included a tarpaulin apron suspended from the cage surface to a 1m depth. The apron was used to temporarily keep spawned eggs from passing through the cage mesh. Fifteen female and five male fish were placed in the spawning cage at a stocking density sufficient to encourage spawning activity without promoting aggressive behavior among the males (Joe Brown, OSC, St. John's, NF, pers. comm.). In early May 1995 fish were randomly selected from the cod farm, and sex determined by cannulation, until the required number of each gender was obtained. The fish were immediately placed in the adjacent spawning cage, thus minimizing the amount of stress caused by handling.

Spawning was monitored by collecting eggs from the spawning cage on a weekly basis until all females were spent. Lengths and weights of the 20 fish in the spawning cage were recorded on July 6 after spawning was complete (Table 2.1).

Ovaries of wild cod collected from Smith Sound on May 4, 1995 were examined visually to determine maturation stage (Appendix H). The fish were caught in Smith Sound, using the otter trawl described in Chapter 1. Two tows were performed on the same day in close proximity to one another (tow 1 at 48° 11.94' latitude by 53° 34.46' longitude, n = 36 fish; tow 2 at 48° 09.79' latitude by 53° 40.19' longitude, n = 64 fish). These ovaries, in conjunction with the cannulation data taken 24-25 April, 1995 from wild Smith Sound cod, were compared with farmed cod to estimate initial timing of spawning.

Fertilized eggs were collected from the spawning cage on eleven dates between early May and late June. The eggs were removed from the spawning cage with a large aquarium dip net and placed in plastic bags containing approximately one litre of water taken from the spawning cage. The bags were then sealed and placed on ice in a cooler. To maintain water temperature in the cooler the bags were kept out of direct contact with the ice by using newsprint. Water temperature in the bags was recorded and the eggs were then transported to the MSRL (3 hour highway trip). The water temperature was recorded again at the MSRL. The change in temperature was insignificant (~0.1°C).

Several attempts were made throughout the month of July 1995 to collect fertilized cod eggs in the Random Island region of Trinity Bay. A neuston net was used for sampling the waters around the island. The net used plankton mesh (333 μm) with a sealed end to minimize stress on the eggs from towing. The net opening was 28 cm x 28 cm, and two floats were used to keep the net at the surface. After several tows at the surface only a few eggs were found. Therefore the floats were removed and the net allowed to sink to ~1m depth. More eggs were recovered from below the surface. The eggs were stored in the same manner as eggs collected from the farm and subsequently brought to the MSRL for examination. No samples brought to the laboratory yielded enough cod eggs for analysis. Hence comparison of eggs from farmed cod were made to published data on eggs from wild northern Atlantic cod.

Examination of eggs in the laboratory

Once at the MSRL, eggs were placed in a large beaker and treated with a low concentration of Wescodyne (1% activated iodine) for 10 minutes to kill potentially pathogenic bacteria and fungi (Piper *et al.* 1982). Dead (opaque) eggs were removed and the remainder placed in plastic incubators (~ 8 litre capacity), with mesh siding to allow water exchange, at densities of about 200 ml of eggs per incubator. The incubators were maintained in a well aerated bath. If the laboratory water temperature differed from the cod farm water temperature by more than ± 0.5°C, the bags of eggs were placed directly into the bath until the temperatures approached equilibrium. This was required to prevent temperature shock to the eggs coming from the field. Temperatures were recorded and the incubators were checked for dead eggs on a daily basis.

For each batch of eggs arriving at the lab, the stage of development was checked using a stereomicroscope with an ocular micrometer. The diameters of thirty randomly sampled eggs were measured (± 0.001 mm). At 100% hatch, 20 larvae lengths were recorded (TL). Two batches of larvae were transferred to 15 litre aquaria, at densities of 30 larvae/l, for survival experiments. Filtered and UV sterilized seawater was used to prevent any potential food reaching the cod larvae. Daily observations were made of the temperature. The time to 50% and 100% mortality was determined. Water temperature fluctuated (~ ± 0.5 °C/day) with the temperature of the seawater inflow to the MSRL throughout the experiments.

2.2 Results

Female farmed cod, cannulated for oocyte development on April 17-18, 1995, were significantly larger than their wild counterparts sampled on April 24-25, 1995, both in length and weight (one-way ANOVA, Table 2.2). On average the farmed cod were 10 cm longer and 2200 g heavier than the wild cod. The ovarian biopsies revealed that 52 % of the farmed cod were in the final stage of oocyte maturation, and that some may have commenced spawning (Appendix F; Figure 2.1). Oocytes that are 1.0 mm or larger are in the final stage of maturation which involves hydration and subsequent release into the water column. Hydrated eggs are normally released in about three days (Kjesbu *et al.* 1990). All oocyte samples came from the oviduct, hence the presence of hydrated oocytes suggests the fish had just spawned or will spawn in the immediate future. Approximately 30 % of the farmed fish had oocytes of 1.5 mm in size; thus spawning may have started prior to their placement in the spawning pen on May 2, 1995 (Appendix F; Figure 2.1). The cage water temperature was 2.0°C on April 17-18 (see Figure 1.3).

Wild cod from Smith Sound, Trinity Bay, sampled on April 24-25 (Appendix B), one week after the farmed fish were sampled, were slightly behind in their oocyte development. Only one wild fish had oocytes of 1.0 mm in size, while 76 % had oocytes of 0.7 mm diameter (Appendix G; Figure 2.1). The bottom and surface temperatures at the sampling site in Smith Sound were -0.97 and 1.6°C respectively on 25 April. The wild fish were caught near the bottom in sub-zero water. Assuming oocyte maturation of the wild cod would occur within the temperature range recorded on the day of sampling, and using 0.7 mm as the most advanced oocyte for the majority of fish, an oocyte development model for sub-zero temperatures (Smedbol and Wroblewski 1997) predicts the time to initiate spawning would be 37-46 days after the date of sampling. Therefore, the wild fish cannulated in April would initiate spawning in late May or early June.

Females from two groups of Smith Sound cod sampled on May 4, 1995, possibly from the same wild aggregate sampled in late April, showed differing stages of ovary development. Group one (n = 36) had 19 females of which only one contained hydrated oocytes. Group two (n = 64) had 23 females of which 16 had hydrated oocytes. The mean (± SE) lengths and weights for the two groups were 49.4 (± 1.26) cm and 1063 (± 90) g, and 53.7 (± 0.69) cm and 1313 (± 56) g respectively. The second group was significantly larger for both length ($F_{1, 97} = 10.35$, $p = 0.002$) and weight ($F_{1, 97} = 6.19$, $p = 0.015$).

Egg collection from the spawning pen began on May 4 and ended on June 22, 1995 (Table 2.3). Between June 22 and July 6 all the fish in the spawning pen finished spawning. Consequently on July 6 the fish were measured and returned to the main pen. Taken together with the cannulation data from above, the spawning period of the farmed cod would therefore have been from mid-April to late June 1995. During the spawning period the temperature in the pen fluctuated from 2°C in mid April to 7°C by the end of June, dropping briefly to sub-zero on four occasions (Figure 1.3).

Only four batches of eggs produced enough larvae ($n \geq 20$) for larval lengths to be measured and only two larval batches were large enough ($n \approx 900$) for the survival experiment (Table 2.3). There were significant differences among the mean egg diameters of the 10 batches of eggs collected ($F_{9, 290} = 45.95$, $p < 0.0005$; Table 2.3), hence the range and median were 1.294 - 1.460 mm and 1.394 mm respectively. There were also significant differences among the means of the four batches of larval lengths (($F_{3, 76} = 2.84$, $p = 0.044$; Table 2.3), with a range and median of 4.297 - 4.450 mm and 4.35 mm respectively. The average survival times during the starvation experiments were 67 °days and 106 °days for 50% and 100% mortality respectively (Table 2.3) ("Degree days" was calculated as the sum of the average daily temperatures). Mean temperature during the starvation experiments was 7.5°C, with minimum and maximum values of 5.8°C and 9.3°C respectively.

2.3 Discussion

During 1995, the farmed cod initiated spawning around mid April and finished near the end of June, approximately the same spawning window observed for wild cod in Trinity Bay (Smedbol and Wroblewski 1997). The initiation of spawning coincided with warming of near surface waters of Gooseberry Cove above 2°C. At the MSRL captive cod start spawning when the water temperature reaches about 2°C (Larry Crim, OSC, St. John's, NF, pers. comm.). Thus it appears that the farmed cod exhibited typical spawning time. The wild cod in Smith Sound appeared to begin spawning around the beginning of May, at least for larger females, which is very close to the start of spawning for the farmed cod. Having overlap in the spawning periods of farm-held and wild fish is encouraging for the grow-out and release enhancement strategy. After release, farmed cod would be spawning at the same time as the wild cod, thus increasing the likelihood that farmed and wild cod would interbreed (See Chapter 3 for evidence that released farmed and wild cod integrated). It also suggests that both farmed and wild cod respond to the same environmental cues for the timing of spawning. Even though the wild cod were caught in sub-zero water, the surface layer was approaching 2°C. It's possible that periodic, vertical migrations (Wroblewski *et al.* 1995) of the wild cod into the warm surface water provided the stimulus to initiate spawning.

Smedbol and Wroblewski (1997) estimated a spawning period of mid-June to mid-July for inshore Trinity Bay cod for the years 1991 and 1992. Why is this spawning period at a later time of year than what was observed in 1995 for wild Trinity Bay cod? The fish sampled in Smith Sound may not be a component of the bay stock and further sampling in June and July may have revealed cod spawning inshore. There may have been changes in the environment (cold temperature) during 1991-1992 that would cause a delay in spawning. Hutchings and Myers (1994b) found significant interannual variation in spawning time for cod stocks on Grand Bank and St. Pierre Bank with expected variations up to 48 days. There may also have been spawning in Trinity Bay from May through to the end of July, since some cod eggs were collected in the wild during July, 1995. The narrower spawning window of the wild cod sampled in 1991 and 1992 compared to the farmed fish is easily explained. Well fed fish produce more eggs (see Chapter 1). More eggs result in more batches to release, and more batches result in a longer spawning period (see Kjesbu *et al.* 1996, and Hutchings and Myers 1993 for a discussion of the ecological implications). The spawning period of the farmed cod was similar in duration to Norwegian cod raised from the egg (Kjesbu 1989).

The wild fish cannulated in April were not expected to spawn until late May or early June based on the oocyte development model, yet fish of smaller size sampled in early May showed the majority of females had hydrated oocytes. The assumption of constant temperature may have caused an overestimation of the time to initiate spawning. Cod will likely move into warmer water prior to spawning (Wroblewski *et al.* 1995) and thus speed up the process, since time to spawning and spawning period are dependent on temperature (Kjesbu 1994).

Kjesbu (1994) reviewed studies on both Norwegian and Icelandic cod that suggest larger cod spawn earlier in the wild, yet could not find a significant relationship between fish length and time of spawning for Arcto-Norwegian cod. Larger cod from the northern Gulf of St. Lawrence started to spawn earlier than smaller cod during 1993-1995 as evident from trawl catches (Ouellet *et al.* 1997). Hutchings and Myers (1993) found that smaller cod spawn earliest in the wild based on analysis of 46 years of research trawl survey data from the Northwest Atlantic. The results of this study suggest that larger females in cod farms spawn earlier than in the wild, but caution is advised since the sample sizes were relatively small and only one spawning season was studied. It was also apparent that the aggregate of cod in Smith Sound were at various stages of development depending on what location was sampled.

Several of the egg batches transported to the MSRL had high mortality prior to hatching and immediately after hatching (high numbers of larvae with bent spines). Thus only two batches produced enough larvae for the starvation experiments. Of the eggs that did survive in the lab, their diameters and larval lengths were similar to wild eggs and larvae (Miller *et al.* 1995; Pepin *et al.* 1997). The survival times for larvae without food were quite long and likely comparable to wild larvae. At the MSRL cod eggs are successfully raised to metamorphosis from farmed cod broodstock, suggesting that cod held and fed in captivity will produce good larvae (Gotceitas *et al.* 1996).

There are several explanations why high mortality was observed with the eggs collected at Gooseberry Cove cod farm. First, vibrations and shaking of eggs in the early stages of development (during transportation to the MSRL) may have caused high levels of abnormalities and mortality (Hempel 1979). All the eggs collected at the farm were in the early blastodisk cleavage stage, and three hours of transportation may have been stressful for them. Collection of eggs in the later stages of development was not possible since retention time in the spawning pen was low.

Secondly, some eggs collected at the farm may have come from poor quality batches. Cod are batch spawners and may produce 15-20 batches of eggs throughout the spawning season (Kjesbu 1989). Egg quality is directly related to batch number with highest viability during period of peak spawning (Kjesbu 1989; Kjørsvik 1994). As spawning progresses, egg size decreases such that egg dry weight is reduced by 20-30% from the first to the last batch (Kjesbu 1989). In my study, eggs came from a group of female cod rather than individuals. Thus it was impossible to track individual fish for peak spawning and egg quality. Egg diameter did not decrease with batch number since batches were mixed. Therefore, it was possible that many samples collected were from early and late batches of individual fish. Peak spawning may have occurred during late May and early June at the farm since batches of eggs collected during that time were the most viable (eggs produced enough larvae for survival experiments, Table 2.3).

Thirdly, it has been well documented that the nutritional state of broodstock fish is critical for the production of viable eggs in teleost fishes (reviewed by Luquet and Watanabe 1986; Kjørsvik *et al.* 1990; Bromage *et al.* 1992). Farmed fish may require a diverse group of "natural feeds" to optimize production of viable eggs. While the farmed Trinity Bay cod were fed a diet that consisted of capelin, herring, or squid, the feed may have lacked essential nutrients required for improved production of viable eggs.

Finally, there was the stress of handling the cod. The spawning fish were removed from one pen, cannulated to determine sex, and placed in an adjacent pen at the beginning or during their spawning cycle. This short term exposure to stress may have been a precursor for poor egg viability. Stress during the spawning season causes spawning activity to be out of phase with ovulation, leading to poor viability of the eggs (Kjørsvik 1994). Placing fish in the spawning pen well in advance of spawning may alleviate this problem in future studies by allowing a period of recovery from stress.

The hypothesis, that farmed cod would spawn in sea cages similarly to wild cod, would be accepted if comparison to Smith Sound cod were used as a criterion (ie. similar time to initiate spawning). Damage by transportation of the eggs cannot be dismissed as a cause of mortality. Future studies should examine the viability of eggs from captive wild cod on site (at the farm).

Table 2.1: Data from 15 female and 5 male Atlantic cod, *Gadus morhua*, placed in a spawning cage at the Gooseberry Cove cod farm. The fish were placed in the spawning bag on May 2, 1995, but the data was collected on July 6, 1995 after all fish were spent. Fertilized eggs were collected from these fish throughout the spawning period. None of these fish had *L. branchialis* parasites.

fish #	tag # (pink)	length (cm)	whole weight (g)	sex (M/F)
1	k50251	68.0	2830	M
2	k50252	67.0	3190	F
3	k50253	71.0	3850	F
4	k50254	67.0	3460	F
5	k50255	66.0	3320	F
6	k50256	70.0	3510	F
7	k50257	61.5	2930	M
8	k50258	69.0	3540	F
9	k50259	69.5	3860	F
10	k50260	66.5	2960	F
11	k50261	66.0	3940	M
12	k50262	66.0	3180	M
13	k50263	72.5	3600	F
14	-	74.5	4340	F
15	-	64.5	2700	F
16	-	80.5	5190	F
17	-	71.5	3640	F
18	-	67.5	3370	F
19	-	66.0	2970	M
20	-	68.5	3340	F

Table 2.2: Size of farmed and wild female Atlantic cod, *Gadus morhua*, that were cannulated for oocyte development in April, 1995 (Appendix A, B). ANOVA results are given as p:*F* where *F* has *df* 1,124 for length, and 1,123 for weight (one fish was not weighed).

	n	length (cm)		weight (g)	
		mean (± SE)	median	mean (± SE)	median
farmed	75	67.6 (0.6)	68.0	3911 (100)	3900
wild	51	57.7 (0.9)	57.0	1718 (105)	1558
ANOVA		<0.001 : 95.3		<0.001 : 215.5	

Table 2.3: Collection dates in 1995 of spawned Atlantic cod, *Gadus morhua*, eggs from Gooseberry Cove cod farm in Trinity Bay. Temp. = temperature at the cod farm. Quantity is volume (ml) of eggs collected. Egg stage represents egg development or number of blastomeres at time of arrival at the MSRL. Egg diameters were measured on arrival (n = 30). Larval lengths were recorded at 100% hatch (n = 20). Survival time was time for 50% and 100% mortality with selected larval batches. Numbers in parentheses are standard errors. "-" = not measured.

date 1995	temp. (°C)	quantity (ml)	lab temp. (°C)	egg stage	diameter (mm)	length (mm)	survival (°days)
May 4	-	100	2.1	4-16	1.333 (.010)	-	-
May 7	-	<50	1.2	died	-	-	-
May 12	1.0	200	1.3	4-16	1.294 (.007)	-	-
May 15	1.5	<50	2.1	-	1.296 (.008)	-	-
May 19	3.5	<50	2.2	-	1.460 (.010)	-	-
May 29	5.0	200	4.3	8-16	1.454 (.006)	4.297 (.032)	79 & 108
June 2	4.5	200	3.1	16-32	1.418 (.011)	4.362 (.029)	55 & 104
June 6	6.0	250	5.0	16-32	1.390 (.009)	-	-
June 12	5.5	100	5.5	32-64	1.399 (.009)	4.450 (.047)	-
June 16	5.5	300	6.4	16-64	1.400 (.010)	-	-
June 22	6.4	200	6.5	64-128	1.377 (.006)	4.388 (.042)	-

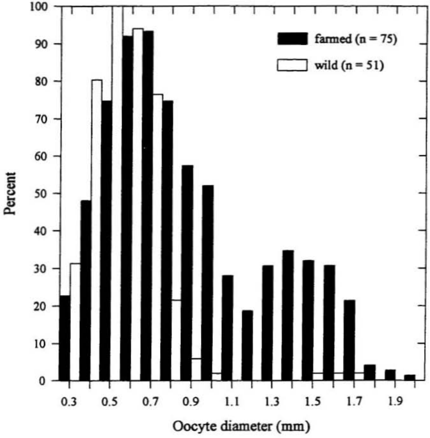

Figure 2.1: Percent of farmed Trinity Bay cod sampled on 17 April 1995 and wild Smith Sound cod sampled on 24-25 April 1995 with oocytes of each diameter.

CHAPTER 3

Post-release movements and survival of farmed cod

It was essential to determine if long-term captivity (farming) modified cod behavior so that it seriously impeded post-release survival and reintegration with the wild population. Therefore on May 1-2, 1995, 20 farmed and 17 wild adult cod from Smith Sound, Trinity Bay were released together at the Gooseberry Cove cod farm after being surgically-implanted with pinger transmitters. To test the hypothesis that farmed cod would remain at the release site longer than wild cod, the presence of sonically-tagged fish near the farm was continuously monitored. A second objective of the sonic tagging and tracking experiment was to determine if farmed cod would reintegrate with wild bay cod after their 3 years of captivity. To test the hypothesis that released farmed cod would reintegrate with wild cod, relocation sites of sonically-tagged fish in Trinity Bay were compared between farmed and wild cod throughout several months post-release. As well, recapture locations of farmed and wild cod, tagged below the dorsal fin with T-bar anchor, external tags, were documented and compared to see if both groups of fish were being caught in similar locations.

3.1 Materials and Methods

Tagging of farmed and wild cod

The farmed cod (see Table 3.1) were initially caught in a cod trap during June 1992, near East Random Head (see Figure 1.2) and remained at the cod farm in

Gooseberry Cove for three years prior to release. Wild cod were caught in Smith Sound on April 25, 1995 (see Table 3.1) and transported to a holding pen adjacent to the farm prior to the release (see Figure 1.2).

On December 8, 1994, 20 farmed cod ranging in length from 57.5 to 74.5 cm and weighing 3-6 kg (Table 3.1), were removed from the pen and fitted with pinger transmitters. The sonic transmitters (VEMCO Ltd. V16-6H, 9.0 cm long and 1.6 cm in diameter, 34 g weight in air) were implanted into the body cavities of fish anesthetized with MS-222 (Jolly *et al.* 1972) following the surgical procedures described by Templeman and Fleming (1962). The sonically-tagged fish were then returned to the pen where they remained for 5 months until the day of release (May 1 or 2, 1995). The V16-6H transmitter is powered by a lithium battery that allows signal emission for about 196 days. The transmitters were deactivated (sleep mode) until late April, 1995 to conserve battery life. Individual fish were identified by frequency (50, 60, 65.5, 69 or 76.8 kHz) and pulse period (specific values in the range 1000-1700 msec) of the transmitter signal.

On April 25, 1995, 17 wild cod caught in Smith Sound were placed in tubs of continuously flowing water, at low stocking densities, and transported to the farm site. The fish ranged in size from 62 to 89 cm and weighed 2-5 kg (Table 3.1). They were placed in a holding pen adjacent to the farm on April 27 and given one day to recover from the stress of being moved. On April 28 nine fish were implanted with sonic transmitters and allowed to recover for two days before their release on May 1. The remaining eight wild cod were implanted with sonic transmitters on May 1 and released on

May 2.

On April 25 two large wild cod (89 and 92 cm, and 3.6 and 4.8 kg respectively) caught in Smith Sound were implanted with sonic transmitters and immediately released in Smith Sound. Searches were made during the subsequent spring and summer to relocate all released fish.

To ascertain the fishing mortality and movements of released farmed cod, 200 cage-held fish were used in a tag and recapture experiment. On April 17-18, 1995, the fish were tagged with T-bar anchor, external tags (Appendix A), attached to the base of the anterior dorsal fin (Templeman and Fleming 1962). These farmed fish were released simultaneously with the sonically-tagged farmed fish on May 1-2 (approximately 100 fish per day). For comparison, 219 wild cod caught in Smith Sound on April 25 were also tagged with T-bar anchor, external tags and immediately released. Information on these fish can be found in Appendix B.

Monitoring sonically-tagged cod released at the farm

On May 1, 1995 ten farmed and nine wild, sonically-tagged cod were released together at the farm. On May 2 a second release was performed with the remaining sonically-tagged fish (ten farmed and eight wild). On May 1 a VEMCO VR-60 receiver was installed at the farm. The receiver utilized a VEMCO Ltd. VH65 omni-directional hydrophone attached at the end of a 3 m cable that continuously monitored for the presence/absence of sonically-tagged cod. The maximum range of detection for the hydrophone was 0.7 nautical miles (or 1.3 km). The entire width of the cove was within the detection range (Figure 3.1). The hydrophone was maintained at the farm site for the duration of the study (May 1 - July 21, 1995). The receiver recorded the time and serial number of detected transmitters (fish). The time to perform one detection cycle for all 37 transmitters was 2-3 minutes (depending on how many transmitters were present during the cycle). Periodic visits were made to the farm to download the data from the receiver into a laptop computer, and also to change the 12 volt battery supplying power to the receiver. The receiver was kept at the farm until July 21, 1995, at which time no signal had been recorded for 30 days.

Sonically-tagged farmed and wild cod were relocated in Trinity Bay throughout the months following release. Three surveys were conducted to document movements of the fish away from the farm site: one at 24 hrs after second release, a second survey at two weeks, and a third at 4 months. A manually operated, directional hydrophone (VEMCO Ltd. V-10) attached by a three meter cable to a VEMCO VR-60 receiver was used in the search for sonically-tagged fish that moved away from the release site.

Data analysis

The three month time series for transmitters detected at the farm was first converted to data files for individual fish. Then each file was binned to 30 minute intervals to facilitate analysis. Two-way ANOVA's were performed on the data to test for significant differences in time to leave the farm, among the groups (farmed and wild) and release dates (May 1 and May 2, 1995) using MINITAB with type I error rate $\alpha = 0.05$. Plots were constructed of the number of fish remaining at the farm site versus time to explore their initial response to release (hours) and longer term behavior (days).

3.2 Results

To test whether or not the released farmed cod remained at the farm site longer than wild cod, a time criterion had to be assumed that would signify the fish had left the release site (ie. a specified amount of time with no detection by the omni-directional hydrophone). Initially the criterion was set at 48 hours since this would be ample time (based on swimming speed of cod and random movement from the release site) for the fish to leave the area of detection (Figure 3.1). The ANOVA with a 48 hour criterion showed a significant difference among the groups ($F = 12.77$, d.f. = 1, 33 $p = 0.001$). However the residuals were not normal. A randomization procedure was used to generate a p-value that was not based on a theoretical distribution. This p-value was generated from randomizations of the MSE (Mean Square Error) term from the ANOVA table, as an indication of the model being used. The randomized p-value (0.007) was similar to the theoretical p-value (0.0062) for the model after 5000 randomizations. Therefore it was assumed that the p-values for each part of the model from the ANOVA table could be trusted (groups, release date, interaction).

Since the result of the 48 hour criterion showed a significant group (farmed vs wild) effect, significance at other time criteria were tested. The results of all criteria tested are shown in Table 3.2. Farmed cod remained at the release site significantly longer than wild cod for criteria up to and including five days. For a time criterion greater than five days, there was no significant difference in time to leave the release site between the groups. There was no significant difference between release days or for the interaction of groups and release day, except for the time criteria of one, four, and five days where the interaction was significant. All other time criteria also had non-normal residuals; therefore randomizations were performed similar to the one performed on the 48 hour data. All randomization tests showed similar p-values to the theoretical F-distributions; hence theoretical F-distributions were used to test components of the model.

Since there was no significant difference between the two release days of farm and wild cod (Table 3.2), the time to leave the release site was pooled (one release per group). The initial response to release indicates how long both groups may associate with the approximately 800 captive cod remaining in the farm, or some physical aspect of the farm. For this analysis it was assumed that sonically-tagged cod were continuously present at the farm unless there was no detection for a period of 30 minutes (Figure 3.2). All wild cod moved away from the farm (outside the zone of detection) by 2.5 hours, while the farm cod took much longer. After 10 hrs 50% of the farm cod were still present at the farm. (Note: Several farmed fish, released with external T-bar anchor tags, were observed swimming around the farm in the same direction as the captive fish several hours (and days) after being released.)

For the long term response to release, no time criterion was assumed. Instead, fish remaining within the detection zone (which was monitored continuously) were counted on a daily basis until all the fish had disappeared (Figure 3.3). A fish detected even once during the day was considered present. The majority of the wild fish left within the first day of release while the majority of the farm fish took longer. However, all farmed cod did eventually leave. After about four weeks no farmed fish was detected at the farm. Interestingly, three wild cod appeared occasionally within the detection zone several weeks after the last farmed fish was detected.

Relocation and recapture of sonically-tagged fish in Trinity Bay

Approximately 24 hours after the second release of sonically-tagged farmed and wild fish, a survey was conducted in and around Gooseberry Cove to document how the fish were dispersing. Ten farmed and four wild fish were found within Gooseberry Cove (Figure 3.4a). When several transmitters are in the same area it is possible to miss a fish when using the directional hydrophone. This occurs when multiple signals are being received at the same time. Thus, there may have been more fish in the cove and not identified. It is also possible to miss a fish if the signal from the transmitter is blocked from reaching the hydrophone (eg. a fish may be under a rock). Nine wild fish were detected outside the cove. No farmed fish were found outside Gooseberry Cove on this day (May 3). Therefore ten farmed and four wild fish were unaccounted for.

Approximately two weeks after release a second survey was conducted to locate sonically-tagged fish. Eight fish (4 farmed and 4 wild) were relocated (Figure 3.4b). No fish were found in Gooseberry Cove indicating all had left the release site. Interestingly, Figure 3.3 shows that one wild fish was detected by the monitoring hydrophone at the farm 14 days after release. This fish may not have been present in the cove, or was undetected during the time of the mobile survey two weeks after release. One farmed fish was on Heart's Ease Ledge and another in close proximity. Heart's Ease Ledge is a spawning area for inshore cod (Smedbol and Wroblewski 1997; Wroblewski *et al.* 1996).

A third survey was conducted in August 1995, four months after release, in Trinity Bay. The timing of this survey was set after the wild spawning period to see if sonically-tagged fish remained in the area after spawning. Eight fish (5 farmed and 3 wild) were relocated during this survey (Figure 3.4c). Five (3 farmed and 2 wild) were found in close proximity (the furthest was ≈ 0.5 km) to Heart's Ease Ledge. Again no fish were detected within Gooseberry Cove. Two fish had dispersed far from the release site, with a wild cod relocated in northern Trinity Bay and a farmed cod found in the southern region of the bay (Figure 3.4c).

The two wild cod fitted with sonic transmitters and released in Smith Sound on April 25, 1995 were relocated only once. They were found close to where they were tagged (~ 2 nautical miles further into Smith Sound) and in very shallow water (5-10 m) on May 17 (three weeks after they were tagged). Acoustic surveys and sampling by DFO revealed numerous cod in the area (Rose 1996).

Within one year of release, five sonically-tagged fish (3 farmed and 1 wild) were caught by fishers (Table 3.3). Figure 3.5 shows the sites and dates where fishers caught the fish. Two farmed and one wild fish were recaptured in the second year after release; one farmed cod in the Random Island region. This is further evidence of a resident bay cod population in Trinity Bay (see Wroblewski *et al.* 1995).

Recaptures of fish tagged with T-bar anchor, external tags

Within one year of release, 15 farmed cod and 3 wild cod tagged with T-bar anchor, external tags had been recaptured. It is possible that not all recaptured fish were reported by fishers. However, there is only anecdotal information on this. Of the 219 wild fish tagged and released in Smith Sound (Appendix B), three were recaptured in the western portion of Trinity Bay (Table 3.4). Thirteen of the 15 recaptured farmed fish occurred in Trinity Bay (Table 3.4). The majority of recaptures (12 farmed and 2 wild fish) occurred within four months after release. The farmed fish released experienced a higher fishing (by-catch) mortality than the wild (control) group ($\chi^2 = 8.42$, $d.f. = 1$, $p < 0.01$). Figure 3.6 shows the locations of the recaptured fish, which demonstrates that the farmed cod dispersed throughout Trinity Bay, rather than remaining near the release site. Farmed fish did not remain together as a group, once released. As with sonically-tagged fish, two farmed fish with external tags were caught near the Heart's Ease Ledge spawning ground.

The mean size at release of the recaptured externally-tagged farmed and wild fish was very similar to the mean size of all the fish released for their respective groups. The mean (median) length and weight of the 219 externally-tagged wild fish was 56.6 (55) cm and 1605 (1465) g respectively. The means (medians) for the three recaptured wild fish were 54.3 (55) cm and 1337 (1330) g. The mean (median) length and weight of the 200 externally-tagged farmed fish was 66.4 (67) cm and 3614 (3570) g respectively. The means (medians) for the 16 recaptured farmed fish were 67.5 (67.5) cm and 3857 (3885) g.

3.3 Discussion

For a short period after release several farmed cod maintained an association with their captive counterparts remaining in the cod farm, or some other aspect of the cod farm environment. These cod may have stayed in anticipation of a feeding; yet regular feedings had not resumed at the farm after the winter hiatus. However, this behavior was short lived and within two days all the farmed fish had left the immediate vicinity. A few farmed fish reappeared at the farm later.

Considering the long term response after release, farmed and wild cod did not differ in their time to leave the release site using the five day criterion (ie. no detection for a period of five days). This occurred because after five days some of the wild fish were re-appearing within the detection zone and staying for several days. Also, as the criterion increased, the variation within groups increased. The increased variation was likely a result of some fish leaving immediately while other fish remained in the detection zone for periods of several days. Fish returning after a five day absence were considered to have left the release site since their return may have been coincidence, or the habitat within Gooseberry Cove may have been suitable for the fish. If the fish were associating with the cod captive at the farm site, then one would have expected returns to the release site throughout the three month post-release period. This did not occur. This in itself is important, because farmed cod from this study did not become domesticated, but rather moved away to a spawning site. It also suggests that if one plans to use this "grow-out and release" method as a form of enhancement, then one would want to release the mature fish at least three to four weeks prior to spawning to ensure that fish will move away from the release site.

During the survey one day after release of the sonically-tagged fish, it was evident that the farmed fish were slower to move out of Gooseberry Cove than the wild fish. After being in captivity for three years the farmed fish may have been reluctant to swim into a new environment. Two weeks after the release, relocated farmed fish were still closer to the farm site than relocated wild fish, even though no fish were detected within Gooseberry Cove. This again suggests that farmed fish may not have moved away from the release site as quickly as the wild fish. However, four months after release, three farmed and two wild fish were relocated at or near Heart's Ease Ledge suggesting that farmed and wild cod were reintegrating.

For the recapture data on both the sonically-tagged fish and the fish with external tags, there was an unexpected result. In both cases farmed fish had a higher post-release fishing mortality within the first 3 months after release. There could be several reasons why this occurred. First, three years in captivity with *ad libitum* feeding produced farmed fish that were significantly larger at age than their wild counterparts. These larger fish may be more susceptible to being caught in the fishing gillnets in use (size selective mortality). The size (at release) of recaptured farmed fish was evenly distributed about the median size of the group, and this may have been the size range most susceptible to capture.

Secondly, released farmed fish may have had an attraction to nets since they were accustomed to nets for several years. Once released a farmed fish may have approached a fishing net in anticipation of a feeding and then became entangled. Since the majority of released farmed cod were captured within three months post-release, it may be that it takes about three months for farmed cod to readapt to the wild. The farmed cod from this study were in captivity for three growth seasons prior to release; thus, if only one growth season is required to advance fecundity (see Chapter 1), then post-release fishing mortality may be lower.

Finally, farmed cod were maintained in captivity in near-shore, shallow water throughout the experiment, and they may have become acclimated to those oceanographic conditions. In May, 1995, when the cod were tagged and released, their short term response may have been to move along the coastline in shallow water where fishing gear such as herring nets and lumpfish nets are often set (most prevalent fishing gears for captured fish, see Tables 3.3 and 3.4). However, the two wild cod sonically tagged and released in Smith Sound were also observed in very shallow water, with numerous other wild cod during mid May. This shallow water behavior is common during the spring (Wroblewski *et al.* 1995). By late September farmed cod appeared to be moving into deeper water, as indicated by two transmitter fish caught in 1995 and 1996 at 230 and 92 m respectively.

The recaptures of farmed cod were anomalously high during the first 3 months after release within Trinity Bay. However there were also a few farmed and wild fish being caught in the Random island region during the second year after release (both for externally and sonically-tagged fish). This is consistent with historical tagging data from DFO for the Random Island region (Wroblewski *et al.* 1996) which suggests the farmed Trinity Bay cod may have been part of a non-migratory, inshore spawning stock.

Table 3.1: Information on the 37 sonically tagged cod released May 1-2, 1995 at the farm in Gooseberry Cove, Trinity Bay.

fish #	group	VEMCO tag #	length (cm)	weight (kg)	release date
1	farmed	1265	64.5	4.0	May 2
2	farmed	1266	69.0	4.1	May 2
3	farmed	1267	71.5	4.3	May 2
4	farmed	1268	70.0	4.5	May 2
5	farmed	1269	72.0	5.1	May 2
6	farmed	1270	76.0	6.0	May 1
7	farmed	1271	57.5	3.0	May 1
8	farmed	1272	71.5	5.3	May 1
9	farmed	1273	68.0	4.5	May 1
10	farmed	1274	72.0	3.8	May 1
11	farmed	1275	68.5	4.5	May 2
12	farmed	1276	64.0	4.0	May 1
13	farmed	1277	66.5	4.6	May 1
14	farmed	1278	67.0	5.5	May 2
15	farmed	1279	71.5	4.5	May 2
16	farmed	1280	69.0	4.8	May 1
17	farmed	1281	70.5	4.9	May 2
18	farmed	1282	74.5	5.2	May 1
19	farmed	1283	67.5	4.3	May 1
20	farmed	1284	68.0	4.3	May 2
21	wild	1438	67.0	2.5	May 1
22	wild	1439	62.0	2.2	May 1
23	wild	1440	78.0	4.8	May 2
24	wild	1441	63.0	2.3	May 2
25	wild	1443	75.0	3.2	May 2
26	wild	1444	65.0	2.5	May 1
27	wild	1445	62.0	2.2	May 1
28	wild	1446	79.0	4.0	May 1
29	wild	1447	63.0	2.3	May 2
30	wild	1448	73.0	2.8	May 2
31	wild	1449	75.0	4.7	May 1
32	wild	1450	64.0	2.0	May 2
33	wild	1451	64.0	2.4	May 1
34	wild	1452	89.0	5.3	May 1
35	wild	1453	63.0	2.2	May 1
36	wild	1454	63.0	2.1	May 2
37	wild	1455	80.0	4.6	May 2

Table 3.2: Mean time (± SE) to leave the release site for farmed (F) and wild (W) cod at different criteria for time. p-values and *F*-ratios (p:*F*) are from the ANOVA table and the sources of error are interaction (inter.) release day (rel.) (ie. May 1 or May 2), and group (F and W). All *F*-Ratio's had df = 1,33. END = mean time to leave the release site (no criteria). Items in **bold** are significant at the 95% confidence level.

Criterion (days)	Farmed (hrs)	Wild (hrs)	p:*F* inter.	p:*F* rel.	p:*F* group
0.125	15.38 (2.96)	2.68 (1.13)	0.745 : 0.11	0.200 : 1.71	**0.001 : 13.81**
0.25	17.15 (3.31)	3.47 (1.34)	0.699 : 0.15	0.371 : 0.82	**0.001 : 12.24**
0.5	18.88 (3.21)	6.74 (2.46)	0.976 : 0.005	0.392 : 0.75	**0.008 : 8.05**
1	42.70 (8.08)	7.97 (2.57)	**0.041 : 4.50**	0.060 : 3.78	**<0.001 : 17.41**
2	103.9 (20.3)	20.0 (7.98)	0.322 : 1.01	0.540 : 0.38	**0.001 : 12.77**
3	113.4 (19.8)	26.9 (10.8)	0.387 : 0.77	0.668 : 0.19	**0.001 : 12.79**
4	170.7 (23.4)	45.8 (18.7)	**0.027 : 5.36**	0.082 : 3.22	**<0.001 : 19.85**
5	170.7 (23.4)	53.2 (19.5)	**0.015 : 6.57**	0.145 : 2.23	**<0.001 : 16.98**
6	170.7 (23.4)	93.1 (55.0)	0.540 : 0.38	0.165 : 2.02	0.170 : 1.97
7	170.7 (23.4)	108.0 (57.9)	0.397 : 0.74	0.285 : 1.18	0.293 : 1.14
8	208.7 (31.0)	108.0 (57.9)	0.846 : 0.04	0.689 : 0.16	0.128 : 2.44
9	208.7 (31.0)	108.0 (57.9)	0.846 : 0.04	0.689 : 0.16	0.128 : 2.44
10	208.7 (31.0)	108.0 (57.9)	0.846 : 0.04	0.689 : 0.16	0.128 : 2.44
END	251.3 (40.1)	224.7 (93.4)	0.188 : 1.81	0.272 : 1.25	0.838 : 0.04

Table 3.3: Recapture information on sonically-tagged Atlantic cod (*Gadus morhua*). See Table 3.1 (fish #) for size at release. See Figure 3.5 for recapture sites. F/W = farmed/wild. All fish recaptured within Trinity Bay, otherwise B.B. = Bonavista Bay.

fish #	F/W	date caught	location caught	depth (m)	fishing gear
2	F	20 May '95	Lower Lance Cv.	12	flounder gillnet
5	F	28 Sep '96	Hickman's Hr.	92	baited hook
6	F	2 Jun '95	Brook Cove	7	lumpfish gillnet
8	F	23 Sep '95	W. Random Hd.	230	skate net
9	F	20 Sep '96	Foggy Rock, B.B.	40	baited hook
21	W	20 Sep '95	Curly's Hr.	-	mackeral gillnet
31	W	4 Jul '96	Clarenville	55	flounder gillnet

Table 3.4: Recapture information on T-bar anchor, externally tagged Atlantic cod (*Gadus morhua*). See Appendices A (farmed) and B (wild) for size at release. F/W = farmed/wild. All fish recaptured within Trinity Bay, otherwise B.B. = Bonavista Bay, C.B. = Conception Bay.

fish #	F/W	date caught	location caught	depth (m)	fishing gear
51	F	Aug '95	Heart's Content	-	lumpfish gillnet
61	F	July '95	Old Bonaventure	-	-
75	F	July '95	British Harbour	-	herring gillnet
80	F	June '95	Heart's Desire	-	lumpfish gillnet
84	F	July '95	Port Rexton	-	gillnet
107	F	July '95	Fox Head	22	lumpfish gillnet
138	F	Nov '95	Brookcove	-	herring gillnet
139	F	June '95	Green's Harbour	20	gillnet
148	F	June '95	Heart's Ease Ledge	-	lumpfish gillnet
167	F	July '95	Plate Cove Hd. B.B.	-	lobster pot
194	F	June '95	Bay de Verde C.B.	-	lumpfish gillnet
195	F	Nov '95	Upper Deer Harbour	-	herring gillnet
196	F	Sep '96	St. Jones Within	-	hook and line
204	F	May '95	Dildo	-	herring gillnet
207	F	July '95	White Rock	-	lumpfish gillnet
208	F	Oct '95	Thornlea	-	gillnet
196	W	July '95	Horse Chops	7	lumpfish gillnet
206	W	June '95	Petley	25	-
217	W	Apr' 96	Lower Lance Cove	-	herring gillnet

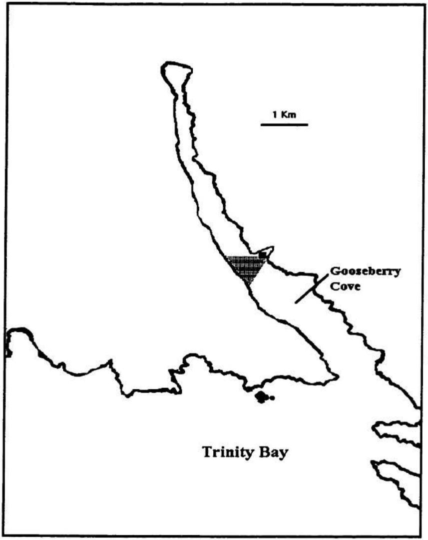

Figure 3.1: Study region of Trinity Bay where sonically-tagged farmed and wild cod were released. The fish were released on 1-2 May 1995. The release site was the Gooseberry Cove cod farm (square). The shaded cone represents the hydrophone detection range.

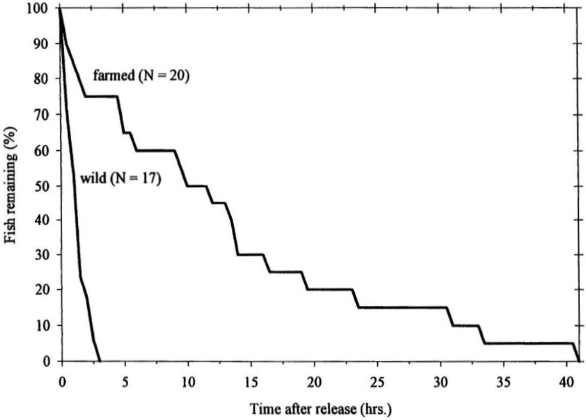

Figure 3.2: The percentage of fish remaining at the release site (cone of detection by the hydrophone shown in Figure 3.1) at various times (hrs.) after release. Fish were assumed to be present unless no signal was recorded for 30 consecutive minutes.

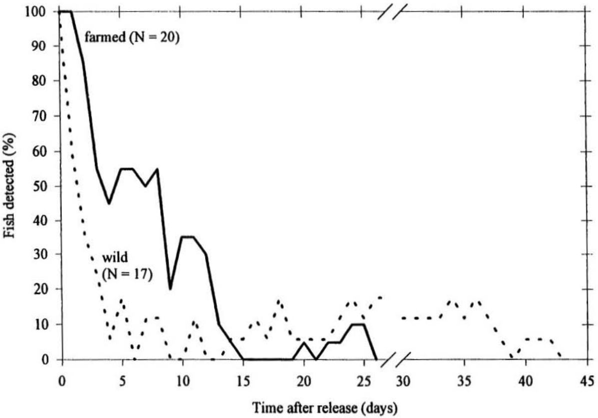

Figure 3.3: Percentage of farmed and wild cod detected by the hydrophone at the farm at various times (days) after release. The graph break represents three days of equipment failure.

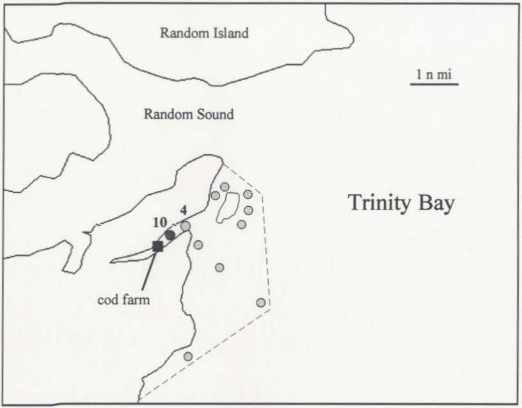

Figure 3.4a: Sites of relocation of sonically-tagged cod on 3 May 1995 (48 and 24 hours after first and second release respectively). Light and dark circles are wild and farmed fish respectively. Note, distributed throughout Gooseberry Cove were 10 farmed and 4 wild fish. Area searched was inside dashed line.

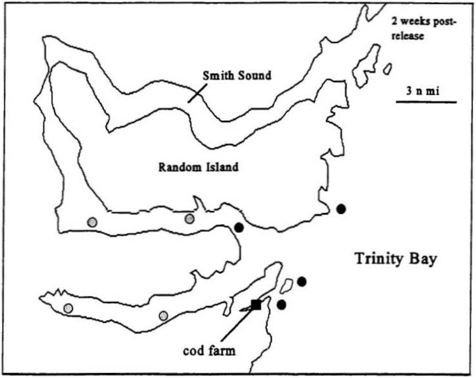

Figure 3.4b: Sites of relocation of sonically-tagged cod two weeks after release. Light and dark circles are wild and farmed fish respectively. Area searched was coastal region shown in figure up to 2 n mi from the shoreline.

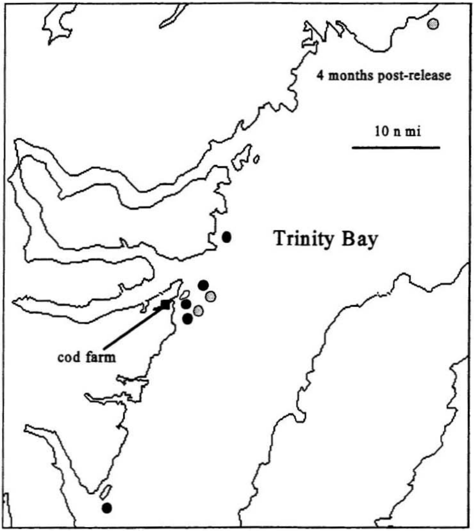

Figure 3.4c: Sites of relocation of sonically-tagged cod in late August 1995, four months after release. Light and dark circles are wild and farmed fish respectively. Area searched was all coastal region of Trinity Bay (including Southern Trinity Bay - not shown) up to 2 n mi from the shoreline.

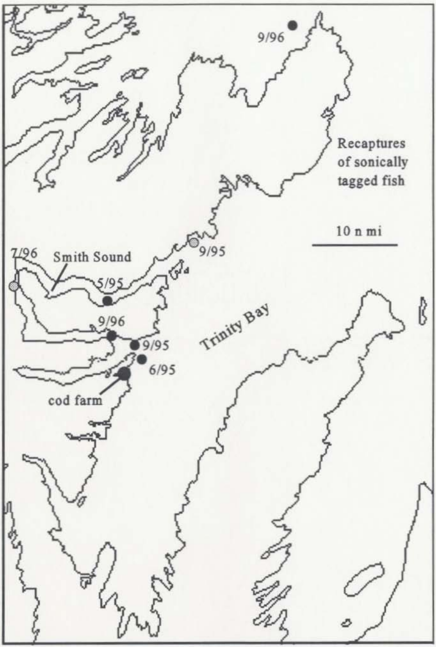

Figure 3.5: Sites of recapture of sonically-tagged cod as of November 1, 1996. Light and dark circles are wild and farmed fish respectively. Dates are positioned near recapture sites (month/year).

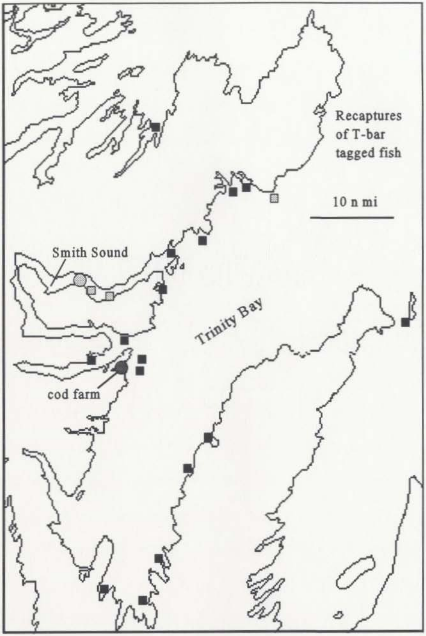

Figure 3.6: Sites of recapture of cod that had external T-bar anchor tags, as of November 1, 1996. Light and dark squares are wild and farmed fish respectively. Wild fish were tagged and released in Smith Sound (light circle). Farmed fish were tagged and released at the farm.

SUMMARY AND CONCLUSIONS

It may be possible to increase the spawning biomass of northern cod in Newfoundland bays by the "grow-out and release" enhancement method. However, reproduction in the wild of released farmed fish was not studied. Cod fed in captivity did quite well in terms of survival, growth, and gains in fecundity, compared to their free-living counterparts. These results are based on maintaining fish for up to four years in captivity, which may or may not be the operational optimum for enhancement. Future research is necessary to determine if significant gains can be made on fish held captive for shorter periods of time, thus reducing the number of years necessary to maintain wild fish. Economic analysis of enhancement by this strategy was not part of this study. See the Working Group on Cod Enhancement Report (1994) for a preliminary economic model.

Captivity had no deleterious effect on spawning behavior, at least in the sea cages. Spontaneous spawning was observed throughout the years in captivity (C. Seward, pers.comm.). Results of egg quality tests appear to indicate no adverse effect of captivity but larger sample sizes are required for a conclusive answer. Transportation of eggs shortly after fertilization may have contributed to the increased mortality observed in the egg and larval trials. As a future consideration, eggs should be incubated and hatched on site to determine if other factors may be contributing to mortality, such as feed quality for the broodstock. Whether released fish spawn successfully in the wild has yet to be determined. By examining ovaries of recaptured fish one could determine if the farmed female spawned, or has experienced atresia, but not if the spawned eggs had been fertilized.

Fishing mortality was higher within the first three months after release for the farmed cod compared to a similar size group of wild cod in Trinity Bay. The captive cod may have grown accustomed to the net pens, thus making them more vulnerable to fishing nets, or fishing mortality may have been a consequence of their large size (the girth of the farmed cod was much higher than for same length wild cod). Farming wild cod, and releasing them after only one year, should be examined in the same manner as this study to investigate post-release fishing mortality. The released fish did eventually revert to a wild state in terms of general activity, as evident from relocations of sonically-tagged individuals and recapture locations. It is assumed that these fish began feeding in the wild, since some were caught on baited hooks. A Norwegian study showed released juvenile cod were feeding like wild cod within a few weeks after release (Blaxter 1994). Future investigations should incorporate the analysis of stomach contents of recaptured farmed and wild cod to test the above assumption.

Identifying the progeny of released farmed fish to determine their spawning success may be difficult. It may be possible, using genetic techniques like nuclear DNA microsatellite probes, to identify cod recruited to the fishery as progeny of released fish, provided the genetic make-up of released fish is known and an appropriate sampling scheme for genetic analyses of fish recruited to the fishery is undertaken (C. Taggart, Dept. of Oceanography, Dalhousie Univ., pers. comm.). Thus another consideration for future research is to genetically identify all released fish. In the present study this was not done, but it's imperative for a stock enhancement program to have some means of measuring success or failure (Cowx 1994). Conventional methods of identifying progeny are not applicable with this form of enhancement (e.g. genetic tagging; Dalhle 1996) since generations of offspring are not produced in captivity. Increases in local cod populations may be considered a natural recovery, even with intervening enhancement efforts, if there is no way to identify the progeny. During the late 1800's efforts by Adolph Nielsen met with such criticism (Baker *et al.* 1992). Nielsen attempted to enhance cod stocks in Trinity Bay through the release of millions of eggs, but had no way to measure the stocking effect. With the form of enhancement investigated in this study, one is able to estimate the potential fecundity that released fish could contribute to spawning in the bays. Thus it might provide data for recruitment models.

Releasing farmed cod to augment the wild spawning biomass in Trinity Bay may not be necessary, given that several million spawning fish were discovered in the bay (Smith Sound) in 1995 (Rose 1996). However, for re-establishing a stock near extinction (eg. Gilberts Bay, Labrador), enhancement may contribute significantly. This form of enhancement (grow-out and release) may also be a useful method for other species around the world.

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Appendix A: Data from farmed Atlantic cod, *Gadus morhua*, sampled at the Gooseberry Cove fish farm on April 17-18, 1995. *L. br.* = *Lernaeocera branchialis*. Fish number [26] not used in study because of a torn caudal fin. These fish were tagged and released on May 1-2, 1995.

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
1	k50976	7	67.0	3380	F	0	*
2	k50977	-	66.0	2980	F	0	*
3	k50978	7	66.0	3000	F	0	*
4	k50979	8	64.0	3100	M	0	-
5	k50980	6	64.0	3050	F	0	*
6	k50981	6	63.0	2800	M	0	-
7	-	7	71.0	4440	F	0	*
8	-	6	59.0	2380	F	0	*
9	-	7	64.0	3480	F	0	*
10	-	6	56.0	2250	M	0	-
11	-	7	70.0	4100	F	0	*
12	-	7	70.0	4480	F	0	*
13	-	6	56.0	2080	M	0	-
14	-	6	63.0	2300	M	0	-
15	-	8	68.0	4110	F	0	*
16	-	7	61.0	2280	M	0	-
17	-	7	62.0	3100	F	0	*
18	-	7	67.0	4150	F	0	*
19	-	6	71.0	5200	F	0	*
20	-	7	66.0	3660	F	0	*
21	-	7	66.0	3800	F	0	*
22	-	6	69.0	3920	F	0	*
23	-	7	67.0	3700	M	0	-
24	-	7	70.0	4300	F	0	*
25	-	7	71.0	3920	F	0	*
[26]	-	7	48.0	1750	M	0	-
27	-	7	67.0	4020	F	0	*
28	-	9	69.0	4460	F	0	*

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
29	-	7	57.0	2020	F	0	*
30	-	7	63.0	2470	F	0	*
31	k50001	-	69.0	4460	F	0	*
32	k50002	-	61.5	3060	F	0	*
33	k50003	-	68.0	3910	M	0	-
34	k50005	-	67.5	4360	M	0	-
35	k50006	-	60.5	2520	F	0	*
36	k50007	-	69.0	4060	M	0	-
37	k50008	-	71.0	3930	M	0	-
38	k50009	-	70.0	4110	F	0	*
39	k50010	-	65.5	3850	F	0	*
40	k50011	-	69.5	3980	F	0	*
41	k50012	-	72.0	4390	M	0	-
42	k50013	-	78.0	5120	F	0	*
43	k50014	-	70.0	4740	F	0	*
44	k50015	-	70.0	4700	M	0	-
45	k50016	-	63.5	3640	F	0	*
46	k50017	-	59.5	2370	M	0	-
47	k50018	-	70.0	4580	F	0	*
48	k50019	-	73.0	5040	F	0	*
49	k50020	-	70.0	4500	F	0	*
50	k50021	-	68.0	3860	F	0	*
51	k50022	-	74.0	4350	F	0	*
52	k50023	-	73.0	4680	F	0	*
53	k50024	-	60.5	2970	M	0	-
54	k50025	-	63.5	2850	F	0	*
55	k50026	-	64.0	3310	M	0	-
56	k50027	-	57.0	2340	F	0	*
57	k50028	-	55.5	3760	F	0	*
58	k50029	-	55.5	2690	F	0	*
59	k50030	-	70.0	4300	F	0	*
60	k50031	-	66.5	3480	F	0	*
61	k50032	-	79.0	6540	F	0	*
62	k50033	-	67.0	3750	F	0	*

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
63	k50034	-	67.0	3600	F	0	*
64	k50035	-	70.0	4480	F	0	*
65	k50036	-	60.0	2690	F	0	*
66	k50037	-	67.0	3540	F	0	*
67	k50038	-	73.0	5240	F	0	*
68	k50039	-	71.0	4470	F	0	*
69	k50040	-	63.5	2980	M	0	-
70	k50041	-	69.5	3840	F	0	*
71	k50042	-	77.0	4580	M	0	-
72	k50043	-	69.5	4280	F	0	*
73	k50044	-	81.5	6770	F	0	*
74	k50045	-	71.5	4010	M	0	-
75	k50046	-	66.0	3250	F	1	*
76	k50047	-	66.0	3730	F	0	*
77	k50048	-	72.0	5030	F	0	*
78	k50049	-	65.5	3570	M	0	-
79	k50050	-	65.5	3720	F	0	*
80	k50051	-	69.0	3870	F	0	*
81	k50052	-	72.0	3100	M	0	-
82	k50053	-	66.0	2770	M	0	-
83	k50055	-	72.0	4700	F	0	*
84	k50057	-	66.0	3900	F	0	*
85	k50058	-	68.0	2540	F	0	*
86	k50059	-	70.0	4600	F	0	*
87	k50060	-	69.0	3100	M	0	-
88	k50061	-	69.0	4490	F	1	*
89	k50062	-	69.0	3900	F	0	*
90	k50063	-	69.0	4460	F	0	*
91	k50064	-	69.5	4980	F	0	*
92	k50065	-	70.0	3800	M	0	-
93	k50066	-	71.0	3700	F	0	*
94	k50067	-	67.0	3900	F	0	*
95	k50068	-	71.0	4000	F	0	*
96	k50069	-	63.0	3140	F	0	*

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
97	k50070	-	63.0	3110	F	0	*
98	k50071	-	65.0	3000	M	0	-
99	k50072	-	68.0	3700	F	0	*
100	k50073	-	66.0	3540	F	0	*
101	k50074	-	62.0	3100	-	1	-
102	k50075	-	72.0	4400	-	0	-
103	k50076	-	66.0	4310	-	0	-
104	k50077	-	69.0	3190	M	0	-
105	k50078	-	68.0	4240	-	0	-
106	k50079	-	69.0	3860	-	0	-
107	k50080	-	60.5	2410	-	0	-
108	k50081	-	72.0	4550	-	0	-
109	k50083	-	61.0	2500	-	0	-
110	k50084	-	60.0	2510	-	0	-
111	k50085	-	69.0	3500	-	1	-
112	k50086	-	72.0	5000	-	0	-
113	k50087	-	67.5	3600	-	1	-
114	k50088	-	63.0	3100	-	0	-
115	k50089	-	70.0	4200	-	0	-
116	k50090	-	58.0	1800	-	0	-
117	k50091	-	66.0	3500	-	0	-
118	k50092	-	67.5	3300	-	0	-
119	k50093	-	67.0	3300	-	0	-
120	k50094	-	60.0	1900	-	0	-
121	k50095	-	66.0	2800	-	0	-
122	k50096	-	69.0	3400	-	0	-
123	k50097	-	64.0	2600	-	0	-
124	k50098	-	64.0	2980	-	0	-
125	k50099	-	66.5	3380	-	0	-
126	k50100	-	67.0	3600	F	0	-
127	-	-	68.0	3500	F	0	*
128	k50101	-	70.0	4200	-	0	-
129	k50103	-	70.0	4450	-	0	-
130	k50104	-	68.0	4290	-	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
131	k50105	-	66.0	3690	-	0	-
132	k50106	-	65.0	3250	M	0	-
133	k50107	-	68.0	3950	-	0	-
134	k50108	-	67.0	3480	-	0	-
135	k50109	-	69.0	4250	-	0	-
136	k50110	-	65.0	3500	-	0	-
137	k50111	-	67.0	3040	-	0	-
138	k50112	-	69.0	4750	M	0	-
139	k50114	-	69.0	4040	M	0	-
140	k50115	-	70.0	4100	-	0	-
141	k50116	-	78.0	4800	-	0	-
142	k50117	-	63.0	3280	-	0	-
143	k50118	-	74.0	5010	-	0	-
144	k50119	-	65.0	3300	-	0	-
145	k50120	-	68.0	4750	-	0	-
146	k50121	-	69.0	3860	-	0	-
147	k50122	-	60.0	2300	-	0	-
148	k50123	-	70.0	4500	-	0	-
149	k50124	-	66.0	4200	-	0	-
150	k50125	-	65.0	3370	-	0	-
151	k50127	-	55.0	2230	M	0	-
152	k50128	-	68.0	3500	-	0	-
153	k50129	-	70.0	3630	-	0	-
154	k50130	-	59.0	2010	-	0	-
155	k50131	-	54.0	2000	M	0	-
156	k50133	-	60.0	3840	-	1	-
157	k50134	-	65.0	3060	M	0	-
158	k50135	-	66.0	4150	-	0	-
159	k50136	-	65.0	4040	-	0	-
160	k50137	-	64.0	3250	M	0	-
161	k50138	-	69.0	3860	-	0	-
162	k50139	-	60.0	3060	-	0	-
163	k50140	-	62.0	3240	-	0	-
164	k50142	-	69.0	3800	-	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
165	k50143	-	62.0	2700	M	0	-
166	k50144	-	64.0	3050	-	0	-
167	k50145	-	64.0	3300	-	0	-
168	k50146	-	67.0	3750	-	0	-
169	k50147	-	63.0	2750	-	0	-
170	k50148	-	64.0	2940	-	0	-
171	k50149	-	62.0	2900	-	0	-
172	k50150	-	73.0	4920	-	0	-
173	k50151	-	66.0	3630	F	0	-
174	k50152	-	58.0	2720	-	0	-
175	k50153	-	65.0	3180	-	2	-
176	k50154	-	68.0	3400	-	0	-
177	k50155	-	69.0	4700	-	0	-
178	k50156	-	69.0	4700	-	0	-
179	k50157	-	71.0	4210	-	0	-
180	k50158	-	68.0	3230	-	0	-
181	k50159	-	67.0	3400	-	0	-
182	k50160	-	75.0	5370	M	0	-
183	k50161	-	66.0	3600	-	0	-
184	k50162	-	71.0	4600	-	0	-
185	k50163	-	71.0	5050	-	0	-
186	k50164	-	64.0	3890	-	0	-
187	k50165	-	67.0	3800	-	0	-
188	k50166	-	62.0	2840	-	0	-
189	k50167	-	62.0	3500	F	0	-
190	k50168	-	64.0	3600	-	0	-
191	k50169	-	65.0	3120	-	0	-
192	k50171	-	61.0	3120	F	0	-
193	k50172	-	62.0	2820	-	0	-
194	k50173	-	57.0	2900	-	0	-
195	k50174	-	71.0	4060	-	0	-
196	k50175	-	63.0	3200	-	0	-
197	k50176	-	70.0	3850	-	0	-
198	k50177	-	68.0	4600	-	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
199	k50178	-	69.0	4190	F	0	-
200	k50181	-	60.0	2800	-	0	-
201	k50182	-	67.0	3570	-	0	-
202	k50183	-	61.0	2930	-	0	-
203	k50184	-	67.0	3750	-	0	-
204	k50185	-	70.0	3430	-	0	-
205	k50186	-	64.0	3600	F	0	-
206	k50187	-	66.0	3270	-	0	-
207	k50188	-	66.0	2890	-	0	-
208	k50189	-	66.0	4320	M	0	-
209	k50190	-	63.0	2500	M	0	-
210	k50191	-	74.0	4300	-	0	-
211	k50192	-	64.0	2700	-	0	-
212	k50193	-	67.0	3540	-	0	-
213	k50194	-	74.0	6400	-	0	-
214	k50195	-	70.0	4480	-	0	-
215	k50196	-	65.0	2590	-	0	-
216	k50197	-	56.0	2090	M	0	-
217	k50198	-	75.0	5180	-	0	-
218	k50199	-	57.0	2250	-	1	-
219	k50200	-	63.0	3060	-	0	-
220	k50201	-	63.0	3200	-	1	-
221	k50202	-	65.0	3130	-	0	-
222	k50203	-	64.0	3270	M	0	-
223	k50204	-	62.0	2700	-	0	-
224	k50205	-	67.0	3020	-	0	-
225	k50206	-	66.0	2790	-	0	-
226	k50207	-	76.0	5910	-	0	-
227	k50208	-	66.0	2930	-	0	-
228	k50209	-	65.0	3010	-	0	-
229	k50210	-	60.0	2580	-	0	-
230	k50211	-	66.0	3270	-	0	-
231	k50212	-	71.0	4640	-	1	-
232	k50213	-	65.0	3370	-	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
233	k50214	-	69.0	3480	M	0	-
234	k50215	-	64.0	2700	-	0	-
235	k50216	-	65.0	3960	-	0	-
236	k50217	-	61.0	3010	-	0	-
237	k50982	6	67.0	3070	F	0	-
238	k50983	6	65.0	2930	F	0	-
239	k50984	7	62.0	3800	M	0	-
240	k50985	6	67.0	3270	F	0	-
241	k50987	6	67.0	3500	F	0	-
242	k50988	7	67.0	2600	M	0	-
243	k50989	6	65.0	2650	M	0	-
244	k50990	7	77.0	4270	F	0	-

Appendix B: Data from wild Atlantic cod, *Gadus morhua*, sampled in Smith Sound, Trinity Bay, NF, on April 24-25, 1995. *L. br.* = *Lernaeocera branchialis*. These fish were released immediately after tagging.

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
1	-	5	46.0	785	F	0	*
2	-	5	49.0	960	F	1	*
3	-	5	51.0	1070	F	0	*
4	-	5	52.0	1060	F	0	-
5	-	5	52.0	1100	M	0	-
6	-	5	52.0	1215	F	0	*
7	-	5	52.0	1260	F	0	*
8	-	5	52.0	1325	M	0	-
9	-	5	52.0	1330	F	0	*
10	-	5	53.0	1140	F	2	*
11	-	5	53.0	1170	M	0	-
12	-	5	53.0	1205	F	0	*
13	-	5	53.0	1240	F	0	*
14	-	5	53.0	1395	F	0	*
15	-	5	53.0	1465	F	1	*
16	-	5	54.0	1260	F	0	*
17	-	5	54.0	1325	F	1	*
18	-	5	54.0	1435	F	0	*
19	-	5	56.0	1445	F	1	*
20	-	5	56.0	1575	F	0	*
21	-	5	57.0	1780	F	0	*
22	-	5	57.0	1815	M	0	-
23	-	5	57.0	1985	F	0	*
24	-	5	59.0	1830	M	0	-
25	-	6	51.0	1110	M	0	-
26	-	6	52.0	1255	M	0	-
27	-	6	53.0	1230	M	1	-
28	-	6	57.0	1400	M	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
29	-	6	57.0	1670	F	0	*
30	-	6	58.0	1540	F	0	*
31	-	6	58.0	1640	F	0	*
32	-	6	59.0	1590	F	0	*
33	-	6	60.0	1580	M	0	-
34	-	6	60.0	1660	F	1	-
35	-	6	60.0	1925	F	0	*
36	-	6	62.0	2130	M	0	-
37	-	6	62.0	2235	F	0	*
38	-	6	63.0	2375	F	0	*
39	-	6	64.0	2200	M	0	-
40	-	6	67.0	2185	F	1	-
41	-	7	55.0	1350	M	0	-
42	-	7	58.0	1590	F	1	-
43	-	7	62.0	1970	M	0	-
44	-	7	62.0	2455	F	0	-
45	-	7	66.0	2170	F	0	*
46	-	8	63.0	2495	M	0	-
47	-	8	65.0	2120	F	0	*
48	-	8	70.0	2600	F	0	-
49	-	8	74.0	3040	F	0	-
50	-	9	85.0	5730	F	1	*
51	h41001	-	55.0	1330	F	0	*
52	h41002	-	69.0	2885	F	0	*
53	h41003	-	53.0	1335	F	0	*
54	h41004	-	53.0	1275	M	0	-
55	h41005	-	63.0	1850	F	0	*
56	h41006	-	51.0	1090	M	0	-
57	h41007	-	55.0	1290	M	0	-
58	h41008	-	57.0	1620	-	0	-
59	h41009	-	64.0	2140	M	0	-
60	h41010	-	51.0	1275	F	0	*
61	h41011	-	65.0	2250	M	0	-
62	h41012	-	59.0	1695	M	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
63	h41013	-	60.0	1810	F	0	*
64	h41014	-	60.0	1765	M	0	-
65	h41015	-	46.0	735	-	0	-
66	h41016	-	52.0	1180	F	0	-
67	h41017	-	50.0	1215	F	0	*
68	h41018	-	55.0	1250	M	0	-
69	h41019	-	57.0	1440	M	0	-
70	h41020	-	57.0	1495	F	0	*
71	h41021	-	51.0	1148	F	1	*
72	h41022	-	69.0	2725	F	0	*
73	h41023	-	55.0	1315	M	0	-
74	h41024	-	54.0	1335	M	0	-
75	h41025	-	58.0	1795	M	1	-
76	h41026	-	54.0	1410	F	0	*
77	h41027	-	56.0	1490	-	0	-
78	h41028	-	61.0	1785	M	1	-
79	h41029	-	58.0	1630	F	0	*
80	-	-	64.0	-	F	0	*
81	h41031	-	55.0	1305	F	0	*
82	h41032	-	46.0	795	-	0	-
83	h41033	-	54.0	1270	M	0	-
84	h41030	-	58.0	1675	F	0	-
85	h41034	-	58.0	1750	F	0	*
86	h41035	-	57.0	1645	M	0	-
87	h41036	-	61.0	1925	F	0	*
88	h41037	-	68.0	2590	F	0	*
89	h41038	-	54.0	1260	F	0	*
90	h41039	-	62.0	2170	F	0	*
91	h41040	-	59.0	1905	F	1	*
92	h41041	-	57.0	1980	M	0	-
93	h41042	-	75.0	3530	M	0	-
94	h41043	-	53.0	1380	M	0	-
95	h41044	-	57.0	1420	M	0	-
96	h41045	-	64.0	2300	M	0	-

fish #	tag #	age	length	whole weight	sex	*L. br.*	ovary biopsy
	(external)	(yr)	(cm)	(g)	(M/F)	(#)	(*)
97	h41046	-	53.0	1335	M	0	-
98	h41047	-	64.0	2010	M	0	-
99	h41048	-	64.0	2285	F	0	*
100	h41049	-	59.0	1810	F	0	*
101	h41050	-	65.0	2290	M	0	-
102	h41051	-	60.0	2065	F	0	*
103	h41052	-	53.0	1320	-	0	-
104	h41053	-	68.0	2310	-	0	-
105	h41054	-	71.0	3005	-	0	-
106	h41055	-	56.0	1565	-	0	-
107	h41056	-	57.0	1690	-	0	-
108	h41057	-	50.0	1055	-	0	-
109	h41058	-	62.0	1260	-	0	-
110	h41059	-	59.0	1480	-	0	-
111	h41060	-	51.0	930	-	0	-
112	h41061	-	55.0	1375	-	0	-
113	h41062	-	60.0	1765	-	0	-
114	h41063	-	56.0	1480	-	0	-
115	h41064	-	55.0	1625	-	0	-
116	h41065	-	64.0	2045	-	0	-
117	h41066	-	58.0	1655	-	0	-
118	h41067	-	54.0	1475	-	0	-
119	h41068	-	70.0	2475	-	0	-
120	h41069	-	59.0	1715	-	0	-
121	h41070	-	55.0	1430	-	0	-
122	h41071	-	64.0	2415	-	0	-
123	h41072	-	54.0	1320	-	0	-
124	h41073	-	64.0	2480	-	0	-
125	h41074	-	51.0	1990	-	1	-
126	h41075	-	54.0	1475	-	0	-
127	h41076	-	54.0	1400	-	0	-
128	h41077	-	61.0	1920	-	0	-
129	h41078	-	51.0	1115	-	0	-
130	h41079	-	78.0	3850	-	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
131	h41080	-	52.0	1100	-	0	-
132	h41081	-	49.0	960	-	0	-
133	h41082	-	52.0	960	-	0	-
134	h41083	-	51.0	1085	-	0	-
135	h41084	-	62.0	1905	-	0	-
136	h41085	-	62.0	2190	-	0	-
137	h41086	-	49.0	905	-	0	-
138	h41087	-	49.0	880	-	0	-
139	h41088	-	46.0	810	-	0	-
140	h41089	-	57.0	1675	-	0	-
141	h41090	-	53.0	1170	-	0	-
142	h41091	-	53.0	1155	-	0	-
143	h41092	-	57.0	1545	-	0	-
144	h41093	-	66.0	2260	-	0	-
145	h41094	-	55.0	1380	-	0	-
146	h41095	-	64.0	1995	-	0	-
147	h41096	-	48.0	875	-	0	-
148	h41097	-	49.0	915	-	0	-
149	h41098	-	51.0	1080	-	0	-
150	h41099	-	57.0	1660	-	0	-
151	h41100	-	54.0	1555	-	0	-
152	h41101	-	79.0	3525	-	0	-
153	h41102	-	54.0	1300	-	0	-
154	h41104	-	62.0	1705	-	0	-
155	h41105	-	50.0	955	-	1	-
156	h41106	-	56.0	1575	-	0	-
157	h41107	-	62.0	2045	-	0	-
158	h41108	-	49.0	1030	-	0	-
159	h41109	-	59.0	1465	-	0	-
160	h41110	-	51.0	1195	-	0	-
161	h41111	-	60.0	1620	-	0	-
162	h41112	-	65.0	2310	-	1	-
163	h41113	-	55.0	1480	-	0	-
164	h41114	-	55.0	1320	-	1	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
165	h41115	-	49.0	1105	-	0	-
166	h41116	-	53.0	1205	-	2	-
167	h41117	-	65.0	1955	-	0	-
168	h41118	-	59.0	1720	-	0	-
169	h41119	-	55.0	1590	-	0	-
170	h41120	-	81.0	6785	-	0	-
171	h41121	-	60.0	1775	-	0	-
172	h41122	-	55.0	1560	-	0	-
173	h41123	-	50.0	975	-	0	-
174	h41124	-	45.0	755	-	0	-
175	h41125	-	67.0	1665	-	0	-
176	h41126	-	53.0	1730	-	0	-
177	h41127	-	56.0	1580	-	0	-
178	h41128	-	51.0	1225	-	0	-
179	h41129	-	55.0	1350	-	0	-
180	h41130	-	40.0	520	-	0	-
181	h41131	-	56.0	1405	-	0	-
182	h41132	-	53.0	1315	-	0	-
183	h41133	-	46.0	800	-	0	-
184	h41134	-	53.0	1195	-	0	-
185	h41135	-	56.0	1380	-	0	-
186	h41136	-	56.0	1590	-	0	-
187	h41137	-	54.0	1310	-	1	-
188	h41138	-	66.0	2415	-	0	-
189	h41139	-	68.0	3070	-	0	-
190	h41140	-	65.0	1935	-	0	-
191	h41141	-	49.0	1035	-	0	-
192	h41142	-	50.0	1145	-	0	-
193	h41143	-	52.0	1210	-	0	-
194	h41144	-	56.0	1370	-	0	-
195	h41145	-	62.0	1700	-	1	-
196	h41146	-	55.0	1330	-	0	-
197	h41147	-	55.0	1360	-	0	-
198	h41148	-	57.0	1665	-	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
199	h41149	-	49.0	1085	-	0	-
200	h41150	-	63.0	2465	-	0	-
201	h41151	-	58.0	1600	-	0	-
202	h41152	-	52.0	1185	-	0	-
203	h41153	-	52.0	1165	-	0	-
204	h41154	-	51.0	1005	-	0	-
205	h41155	-	60.0	1840	-	0	-
206	h41156	-	53.0	1325	-	0	-
207	h41157	-	51.0	1200	-	0	-
208	h41158	-	62.0	1930	-	0	-
209	h41159	-	51.0	1055	-	0	-
210	h41160	-	53.0	1275	-	0	-
211	h41161	-	52.0	1345	-	0	-
212	h41162	-	51.0	1225	-	0	-
213	h41163	-	59.0	1730	-	0	-
214	h41164	-	54.0	1300	-	1	-
215	h41165	-	61.0	1905	-	0	-
216	h41166	-	60.0	1605	-	0	-
217	h41167	-	55.0	1355	-	0	-
218	h41168	-	63.0	2040	-	0	-
219	h41169	-	51.0	1090	-	0	-
220	h41170	-	62.0	2320	-	0	-
221	h41171	-	51.0	1090	-	0	-
222	h41172	-	53.0	1275	-	0	-
223	h41173	-	65.0	2410	-	0	-
224	h41174	-	68.0	2955	-	0	-
225	h41175	-	50.0	1210	-	0	-
226	h41176	-	71.0	3100	-	0	-
227	h41177	-	65.0	2380	-	0	-
228	h41178	-	59.0	1960	-	0	-
229	h41179	-	51.0	950	-	0	-
230	h41180	-	58.0	1690	-	0	-
231	h41181	-	54.0	1260	-	1	-
232	h41182	-	66.0	2270	-	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
233	h41183	-	55.0	1390	-	0	-
234	h41184	-	53.0	1135	-	0	-
235	h41185	-	53.0	1540	-	0	-
236	h41186	-	63.0	1895	-	0	-
237	h41187	-	65.0	2180	-	0	-
238	h41188	-	51.0	1285	-	0	-
239	h41189	-	55.0	1390	-	0	-
240	h41190	-	47.0	865	-	0	-
241	h41191	-	47.0	1000	-	0	-
242	h41192	-	52.0	1165	-	0	-
243	h41193	-	50.0	980	-	1	-
244	h41194	-	51.0	1125	-	0	-
245	h41195	-	54.0	1295	-	0	-
246	h41196	-	49.0	1015	-	0	-
247	h41197	-	47.0	895	-	0	-
248	h41198	-	56.0	1515	-	0	-
249	h41199	-	50.0	1145	-	0	-
250	h41200	-	56.0	1285	-	0	-
251	h41201	-	46.0	915	-	0	-
252	h41202	-	58.0	1810	-	0	-
253	h41203	-	42.0	625	-	0	-
254	h41204	-	59.0	1655	-	0	-
255	h41205	-	45.0	785	-	1	-
256	h41206	-	48.0	1005	-	0	-
257	h41207	-	59.0	1505	-	0	-
258	h41208	-	58.0	1808	-	0	-
259	h41209	-	51.0	1145	-	1	-
260	h41210	-	55.0	1525	-	0	-
261	h41211	-	54.0	2160	-	0	-
262	h41212	-	68.0	2530	-	0	-
263	h41213	-	53.0	1410	-	0	-
264	h41214	-	57.0	1580	-	0	-
265	h41215	-	54.0	1345	-	0	-
266	h41216	-	51.0	1175	-	0	-

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	sex (M/F)	*L. br.* (#)	ovary biopsy (*)
267	h41217	-	55.0	1470	-	0	-
268	h41218	-	49.0	1030	-	0	-
269	h41219	-	33.0	275	-	0	-

Appendix C: Data from farmed Atlantic cod, *Gadus morhua*, sampled at the Gooseberry Cove fish farm on Sept. 7, 1995. *L. br.* = *Lernaeocera branchialis*.

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	gutted weight (g)	sex (M/F)	*L. br.* (#)	liver weight (g)
1	mi06059	7	70.0	4420	3640	F	0	570
2	mi06570	7	69.5	4420	3430	F	0	640
3	k50237	8	79.0	6670	5470	F	0	810
4	k50236	7	71.0	4880	4110	F	0	580
5	k50044	11	84.0	6430	4980	F	0	870
6	k50256	7	74.5	4550	3680	F	0	620
7	mi06532	7	73.5	4940	3970	F	0	640
8	k50226	7	74.0	4540	3670	F	0	530
9	mi06576	7	69.5	4330	3190	F	0	660
10	k50251	7	72.5	3950	3250	F	0	460
11	k50233	7	69.0	4430	3480	F	0	650
12	mi06605	6	67.0	3290	2710	M	0	390
13	mi06529	7	68.0	3950	3180	F	0	480
14	k50260	7	70.0	4120	3310	F	0	550
15	k50228	7	74.0	5200	4160	F	0	730
16	k50235	7	73.0	4530	3720	F	0	590
17	k50230	7	73.0	4940	3950	F	0	680
18	mi06592	7	72.5	5140	4180	F	0	630
19	mi06550	7	73.5	4050	3490	M	0	370
20	k50229	6	71.5	3470	3050	M	0	260
21	k50223	8	75.5	4970	4020	F	0	640
22	k50258	7	72.0	4240	3480	F	0	430
23	k50252	7	71.0	4030	3140	F	0	620
24	mi06611	7	71.0	4960	4170	M	0	560
25	k50234	7	67.5	3740	2840	F	0	550
26	k50262	8	69.0	3830	3280	M	0	390
27	mi06058	8	72.0	4980	4150	M	0	540
28	k50253	7	74.5	4940	4180	M	0	520
29	k50158	7	70.5	3880	3120	F	0	500

fish #	tag # (external)	age (yr)	length (cm)	whole weight (g)	gutted weight (g)	sex (M/F)	*L. br.* (#)	liver weight (g)
30	k50255	7	69.5	4360	3580	F	0	540
31	k50227	7	74.0	5240	4400	M	0	580
32	k50240	7	77.5	5670	4640	M	0	720
33	k50232	7	76.0	5290	4400	M	0	710
34	-	7	76.5	6320	5210	M	0	800
35	k50263	7	75.5	4750	3930	F	0	580
36	k50261	7	68.5	4850	4050	M	0	600
37	k50238	6	64.5	3520	2850	F	0	500
38	k50241	7	71.0	4990	3790	F	0	740
39	k50244	7	77.0	6020	4870	F	0	780
40	k50259	7	72.5	4950	4100	F	0	560
41	k50243	8	74.0	5110	4030	F	0	720
42	k50242	7	78.0	5680	4840	M	0	560
43	mi06588	6	63.5	2770	2290	F	1	340
44	mi06542	6	61.5	2780	2230	F	0	400
45	k50257	6	65.5	3910	3240	M	0	480

Appendix D: Data from wild Atlantic cod, *Gadus morhua*, sampled in Smith Sound, Trinity Bay, NF, on Sept. 26, 1995. *L. br.* = *Lernaeocera branchialis*.

fish #	age (yr)	length (cm)	whole weight (g)	gutted weight (g)	sex (M/F)	*L. br.* (#)	liver weight (g)
1	7	66.0	2710	2490	M	0	80
2	8	68.5	2990	2650	F	0	170
3	6	69.0	2780	2390	M	0	150
4	6	58.0	3070	2610	M	0	270
5	5	57.0	2000	1690	F	0	100
6	5	55.0	1620	1400	F	0	130
7	6	62.5	2560	2050	M	0	260
8	7	76.5	3900	3380	M	1	240
9	5	53.0	1480	1260	F	0	90
10	7	68.0	3060	2640	F	0	250
11	7	68.0	2710	2390	M	0	130
12	6	63.0	2460	2080	F	0	220
13	6	62.0	2790	2200	F	0	240
14	7	65.0	2720	2120	M	0	210
15	7	65.0	2440	2050	F	0	180
16	6	69.0	2880	2390	M	0	250
17	6	57.5	1930	1570	M	0	150
18	6	62.0	2450	1910	M	0	150
19	6	66.5	2720	2390	F	1	150
20	6	61.5	2060	1810	F	0	100
21	6	62.5	2490	2120	F	0	210
22	6	64.5	2390	2030	F	0	210
23	8	75.0	3430	3020	F	0	170
24	6	62.5	2300	1970	F	0	170
25	6	68.0	2800	2420	F	0	160
26	7	72.5	3570	3150	F	1	170
27	7	66.0	2550	2200	M	0	170
28	8	71.0	3050	2590	M	0	100
29	6	64.0	1940	1660	F	0	180

fish #	age (yr)	length (cm)	whole weight (g)	gutted weight (g)	sex (M/F)	*L. br.* (#)	liver weight (g)
30	7	62.0	2410	2020	F	0	230
31	6	60.5	2200	1950	F	0	140
32	6	58.5	2030	1580	M	0	190
33	7	70.0	3530	2940	M	0	170
34	6	65.0	2620	2120	F	0	230
35	7	70.0	3480	3080	M	0	200
36	7	67.5	2870	2440	F	0	230
37	6	62.5	2300	2000	F	0	150
38	6	59.5	2200	1800	F	0	230
39	6	59.5	1980	1650	F	0	180
40	7	71.5	3470	3050	M	0	190
41	7	61.5	2100	1710	F	0	130
42	6	58.5	2180	1710	M	0	180
43	6	60.5	2370	2010	F	0	200
44	7	71.0	3020	2600	F	0	200
45	7	63.5	2780	2330	F	0	210
46	8	63.0	2590	2140	M	0	250
47	7	58.5	2100	1730	F	0	160
48	6	54.0	1710	1420	F	0	110
49	6	63.5	2510	2100	F	0	200

Appendix E: Data from farmed, female Atlantic cod, *Gadus morhua*, sampled at the Gooseberry Cove fish farm on April 4, 1996. Fish 5 and 12 had hydrated oocytes. The gill parasite *L. branchialis* was not found on any of the fish..

fish (#)	age (yr)	length (cm)	whole wt. (g)	gutted wt. (g)	liver wt. (g)	gill wt. (g)	ovary wt. (g)
1	7	77.0	5520	3980	738	154	418
2	7	76.0	5820	4300	760	160	416
3	6	76.0	5600	4140	700	160	498
4	6	77.0	5700	4100	830	142	598
5	7	76.0	5880	3560	762	134	1252
6	7	66.5	3480	2540	426	118	302
7	7	74.5	5120	3700	572	126	470
8	6	73.0	4500	3240	378	130	558
9	7	72.0	5080	3540	592	142	604
10	7	77.5	4940	3560	494	146	522
11	6	70.0	4640	3400	536	92	348
12	7	82.0	7500	4980	1090	170	1136
13	6	75.0	5400	4100	756	114	362
14	8	79.0	6580	4880	840	150	482
15	8	72.5	5060	3380	596	124	712

Appendix F: Oocyte data from 75 female Atlantic cod, *Gadus morhua*, sampled at the Gooseberry Cove fish farm on April 17-18, 1995. Fish number corresponds to fish number in Appendix A. Count refers to number of fish with a given oocyte size.

fish #	oocyte diameter (mm)																	
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1	-	-	-	1	14	26	17	-	-	-	3	17	22	-	-	-	-	-
2	9	28	42	17	4	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	2	4	10	18	8	3	-	-	28	13	12	2	-	-	-	-
5	-	3	12	21	26	18	5	13	2	-	-	-	-	-	-	-	-	-
7	-	-	11	15	16	29	7	2	-	-	3	11	6	-	-	-	-	-
8	-	15	42	34	9	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	6	9	14	17	6	19	21	8	-	-	-	-	-	-	-	-
11	1	25	42	27	5	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	36	33	22	9	-	-	-	-	-	-	-	-	-	-	-	-
15	-	22	44	30	4	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	28	49	22	1	-	-	-	-	-	-	-	-	-	-	-	-	-
18	2	7	42	26	18	5	-	-	-	-	-	-	-	-	-	-	-	-
19	2	26	34	30	5	3	-	-	-	-	-	-	-	-	-	-	-	-
20	-	10	42	42	6	-	-	-	-	-	-	-	-	-	-	-	-	-
21	-	-	1	1	7	17	18	26	-	-	1	1	8	11	9	-	-	-
22	3	37	49	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	2	7	16	33	6	-	-	-	-	24	12	-	-	-	-
25	-	-	1	1	12	27	20	2	1	9	23	3	-	1	-	-	-	-
27	5	31	51	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	15	23	29	17	4	1	-	7	3	1	-	-	-	-	-
29	-	-	1	4	10	26	19	4	13	20	3	-	-	-	-	-	-	-
30	-	9	18	40	27	6	-	-	-	-	-	-	-	-	-	-	-	-

fish #	oocyte diameter (mm)																	
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
31	1	27	57	13	1	1	-	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	3	12	20	17	10	9	-	-	2	16	9	2	-	-	-
35	-	-	-	3	3	16	24	9	1	-	11	21	12	-	-	-	-	-
38	-	3	11	14	46	23	3	-	-	-	-	-	-	-	-	-	-	-
39	-	-	2	3	12	27	21	6	-	11	11	6	1	-	-	-	-	-
40	-	-	-	3	11	26	31	4	-	-	3	13	8	1	-	-	-	-
42	-	1	14	36	26	18	5	-	-	-	-	-	-	-	-	-	-	-
43	-	-	3	9	11	26	17	2	-	-	2	8	14	7	1	-	-	-
45	-	-	-	1	1	12	25	14	1	-	2	8	23	11	2	-	-	-
47	4	21	35	34	6	-	-	-	-	-	-	-	-	-	-	-	-	-
48	-	-	2	15	27	22	8	8	-	-	-	1	3	8	6	-	-	-
49	2	16	24	34	24	-	-	-	-	-	-	-	-	-	-	-	-	-
50	1	17	54	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-
51	-	-	-	3	17	30	22	6	-	5	10	7	-	-	-	-	-	-
52	-	8	17	23	30	20	2	-	-	-	-	-	-	-	-	-	-	-
54	-	12	40	40	8	-	-	-	-	-	-	-	-	-	-	-	-	-
56	-	-	1	-	8	19	12	15	3	-	7	1	6	22	6	-	-	-
57	-	-	1	5	10	20	14	4	1	-	1	5	26	10	3	-	-	-
58	-	16	39	34	10	1	-	-	-	-	-	-	-	-	-	-	-	-
59	-	-	3	16	24	23	5	7	12	9	1	-	-	-	-	-	-	-
60	-	1	-	4	15	25	10	5	12	25	3	-	-	-	-	-	-	-
61	4	11	29	25	25	6	-	-	-	-	-	-	-	-	-	-	-	-
62	-	-	2	1	11	12	12	11	1	-	-	1	16	20	9	4	-	-
63	5	33	49	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-

fish #	oocyte diameter (mm)																	
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
64	-	15	41	35	9	-	-	-	-	-	-	-	-	-	-	-	-	-
65	-	-	-	7	11	31	33	9	-	-	2	-	-	2	5	-	-	-
66	-	-	-	2	14	22	22	18	17	4	-	-	-	1	-	-	-	-
67	-	4	35	36	22	3	-	-	-	-	-	-	-	-	-	-	-	-
68	-	12	27	26	27	8	-	-	-	-	-	-	-	-	-	-	-	-
70	-	-	14	31	33	17	-	3	2	-	-	-	-	-	-	-	-	-
72	-	-	1	9	16	27	20	15	12	-	-	-	-	-	-	-	-	-
73	3	22	35	34	6	-	-	-	-	-	-	-	-	-	-	-	-	-
75	-	6	41	40	13	-	-	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	14	15	23	3	-	1	2	6	10	19	7	-	-	-
77	-	-	-	-	8	8	22	14	8	2	-	-	-	1	17	16	2	2
79	-	-	2	8	17	29	20	3	-	-	3	10	6	1	1	-	-	-
80	-	-	-	-	8	15	36	22	17	2	-	-	-	-	-	-	-	-
83	-	-	-	2	9	18	33	14	1	-	-	1	-	11	9	-	2	-
84	-	3	20	40	27	10	-	-	-	-	-	-	-	-	-	-	-	-
85	-	-	-	-	1	4	9	4	-	1	2	10	38	21	8	2	-	-
86	11	48	36	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
88	-	3	2	7	19	32	13	6	-	-	-	-	10	5	3	-	-	-
89	-	-	3	4	24	11	8	12	-	-	-	2	22	13	1	-	-	-
90	-	-	7	17	25	19	16	12	3	1	-	-	-	-	-	-	-	-
91	-	-	5	25	37	27	5	-	-	-	-	1	-	-	-	-	-	-
93	3	13	30	32	15	7	-	-	-	-	-	-	-	-	-	-	-	-
94	-	-	1	8	13	30	16	3	-	-	-	4	25	-	-	-	-	-
95	7	27	46	19	1	-	-	-	-	-	-	-	-	-	-	-	-	-
96	-	-	-	7	16	22	24	6	-	-	2	12	10	1	-	-	-	-

fish #	oocyte diameter (mm)																	
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
97	-	-	-	-	13	22	15	4	-	-	1	9	23	13	-	-	-	-
99	8	26	26	31	9	-	-	-	-	-	-	-	-	-	-	-	-	-
100	-	3	22	44	24	7	-	-	-	-	-	-	-	-	-	-	-	-
127	-	-	-	8	15	29	12	1	21	14	-	-	-	-	-	-	-	-
total	71	589	1302	1235	1024	1006	705	329	159	112	131	176	342	202	89	22	4	2
count	17	36	56	69	70	56	43	39	21	14	23	26	24	23	16	3	2	1

Appendix G: Oocyte data from 51 female Atlantic cod, *Gadus morhua*, sampled in Smith Sound, Trinity Bay, NF, on April 25, 1995. Fish number corresponds to fish number in Appendix B. Count refers to number of fish with a given oocyte size.

fish #	oocyte diameter (mm)																	
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1	-	6	27	50	17	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	5	58	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	1	14	75	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	11	65	24		-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	11	37	42	10	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	1	13	35	46	5	-	-	-	-	-	-	-	-	-	-	-	-
10	2	33	60	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	4	24	45	27	-	-	-	-	-	-	-	-	-	-	-	-	-
13	1	14	58	24	3	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	34	54	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	3	22	63	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	-	2	31	51	16	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	52	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	21	59	19	1	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	28	51	21	-	-	-	-	-	-	-	-	-	-	-	-	-
20	1	17	37	36	9	-	-	-	-	-	-	-	-	-	-	-	-	-
21	2	16	61	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	1	5	46	39	9	-	-	-	-	-	-	-	-	-	-	-	-	-
29	1	35	57	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	-	21	64	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	-	2	28	42	26	2	-	-	-	-	-	-	-	-	-	-	-	-
32	-	-	23	60	17	-	-	-	-	-	-	-	-	-	-	-	-	-

fish #	oocyte diameter (mm)																	
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
35	-	-	23	42	33	2	-	-	-	-	-	-	-	-	-	-	-	-
37	-	-	2	1	16	28	23	7	-	-	-	-	7	12	4	-	-	-
38	-	-	3	10	32	42	13	-	-	-	-	-	-	-	-	-	-	-
45	-	1	15	44	37	3	-	-	-	-	-	-	-	-	-	-	-	-
47	-	4	42	50	4	-	-	-	-	-	-	-	-	-	-	-	-	-
50	-	-	7	18	47	28	-	-	-	-	-	-	-	-	-	-	-	-
51	-	-	1	14	31	51	3	-	-	-	-	-	-	-	-	-	-	-
52	1	52	47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
53	-	-	37	47	16	-	-	-	-	-	-	-	-	-	-	-	-	-
55	3	33	47	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	-	1	31	43	25	-	-	-	-	-	-	-	-	-	-	-	-	-
63	1	27	51	20	1	-	-	-	-	-	-	-	-	-	-	-	-	-
67	-	2	20	45	30	3	-	-	-	-	-	-	-	-	-	-	-	-
70	-	2	30	53	15	-	-	-	-	-	-	-	-	-	-	-	-	-
71	-	3	31	44	22	-	-	-	-	-	-	-	-	-	-	-	-	-
72	1	8	39	49	3	-	-	-	-	-	-	-	-	-	-	-	-	-
76	-	-	3	23	47	27	-	-	-	-	-	-	-	-	-	-	-	-
79	1	11	39	44	5	-	-	-	-	-	-	-	-	-	-	-	-	-
80	1	9	42	44	4	-	-	-	-	-	-	-	-	-	-	-	-	-
81	-	3	33	55	9	-	-	-	-	-	-	-	-	-	-	-	-	-
85	-	10	45	44	1	-	-	-	-	-	-	-	-	-	-	-	-	-
87	2	28	49	20	1	-	-	-	-	-	-	-	-	-	-	-	-	-
88	-	3	41	48	8	-	-	-	-	-	-	-	-	-	-	-	-	-
89	-	7	52	32	9	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	22	51	26	1	-	-	-	-	-	-	-	-	-	-	-	-	-

fish #	oocyte diameter (mm)																	
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
91	-	-	4	22	63	11	-	-	-	-	-	-	-	-	-	-	-	-
99	-	1	17	54	28	-	-	-	-	-	-	-	-	-	-	-	-	-
100	-	10	46	37	7	-	-	-	-	-	-	-	-	-	-	-	-	-
102	-	9	48	41	2	-	-	-	-	-	-	-	-	-	-	-	-	-
total	33	626	1871	1600	699	202	39	7	0	0	0	0	7	12	4	0	0	0
count	16	41	51	48	39	11	3	1	0	0	0	0	1	1	1	0	0	0

Appendix H: Data from wild Atlantic cod, *Gadus morhua*, sampled in Smith Sound, Trinity Bay, NF, on May 4, 1995. Fish 1 - 36 were collected at a different location than fish 37 - 100 (see chapter 2 for locations sampled). Note the maturity stages for females are: 0 = immature, 1 = eggs forming but no hydration and ovary is flaccid, 2 = some hydrated eggs (< 50%) and ovary increasing in size, 3 = full ovary with > 50% hydration (spawning to occur in immediate future). *L. br.* = *Lernaeocera branchialis.*

fish #	age (yr)	length (cm)	whole wt. (g)	sex (M/F)	mat. stage	*L. br.* (#)
1	4	37.0	405	F	0	0
2	5	49.0	850	F	1	0
3	5	41.0	480	F	0	0
4	5	47.0	780	F	0	0
5	7	68.0	2490	F	1	0
6	4	39.0	430	M	-	0
7	5	49.0	1070	M	-	0
8	5	53.0	1470	F	3	0
9	5	46.0	755	F	0	0
10	7	56.0	1380	M	-	0
11	5	46.0	890	F	1	2
12	5	52.0	1030	M	-	0
13	5	54.0	1255	M	-	0
14	5	49.0	880	F	1	0
15	5	51.0	1055	F	1	0
16	7	62.0	2155	M	-	0
17	5	52.0	1330	F	1	0
18	6	43.0	760	F	1	2
19	6	57.0	1755	F	0	1
20	5	50.0	1090	F	1	0
21	6	64.0	2515	F	1	0
22	5	44.0	775	M	-	0
23	5	41.0	565	M	-	1
24	4	41.0	590	M	-	0
25	5	48.0	980	F	1	0
26	5	46.0	895	M	-	0
27	6	57.0	745	M	-	0
28	5	55.0	1260	F	1	1

fish #	age (yr)	length (cm)	whole wt. (g)	sex (M/F)	mat. stage	*L. br.* (#)
29	7	58.0	1685	M	-	0
30	5	43.0	620	M	-	0
31	9	60.0	1660	F	1	0
32	5	45.0	790	M	-	0
33	5	42.0	525	M	-	0
34	5	50.0	1060	F	1	0
35	4	37.0	400	M	-	0
36	5	46.0	890	M	-	0
37	6	53.0	1040	M	-	0
38	5	60.0	1610	F	3	0
39	5	53.0	1260	F	3	0
40	7	56.0	1425	M	-	0
41	5	56.0	1520	F	3	0
42	6	56.0	1715	F	3	0
43	6	58.0	1450	M	-	0
44	5	54.0	1335	F	3	1
45	7	62.0	2115	F	3	0
46	5	47.0	870	F	1	0
47	8	60.0	1560	M	-	0
48	5	51.0	1130	M	-	0
49	5	45.0	670	M	-	0
50	5	45.0	745	M	-	1
51	7	61.0	2010	F	3	0
52	6	58.0	1620	M	-	0
53	5	43.0	620	M	-	0
54	6	57.0	1675	F	1	0
55	7	62.0	2125	M	-	0
56	4	36.0	395	M	-	0
57	5	53.0	1460	F	3	0
58	6	50.0	975	M	-	0
59	6	58.0	1665	M	-	0
60	6	57.0	1755	M	-	0
61	5	52.0	1010	M	-	0
62	6	59.0	1575	F	3	0
63	7	58.0	1640	F	3	0
64	6	57.0	1360	M	-	0
65	5	48.0	925	F	3	0
66	6	51.0	1095	M	-	0

fish #	age (yr)	length (cm)	whole wt. (g)	sex (M/F)	mat. stage	*L. br.* (#)
67	6	59.0	1575	F	3	0
68	4	45.0	725	M	-	0
69	6	64.0	2655	F	1	0
70	5	58.0	1380	F	1	0
71	6	57.0	1465	M	-	0
72	6	49.0	925	M	-	0
73	6	54.0	1465	F	3	0
74	6	55.0	1215	M	-	0
75	7	60.0	1510	M	-	0
76	6	55.0	1430	M	-	0
77	6	59.0	1675	M	-	0
78	6	51.0	1000	M	-	0
79	7	48.0	920	F	3	0
80	6	55.0	1300	M	-	0
81	5	49.0	925	M	-	0
82	4	44.0	590	M	-	0
83	5	53.0	1095	M	-	0
84	6	56.0	1355	M	-	0
85	5	53.0	1185	M	-	0
86	6	56.0	1545	F	3	0
87	6	53.0	1325	M	-	0
88	6	56.0	1220	M	-	0
89	6	59.0	1795	F	1	0
90	5	51.0	1250	M	-	0
91	5	48.0	1035	F	1	0
92	7	64.0	2600	M	-	0
93	6	54.0	1185	M	-	0
94	6	56.0	1585	F	3	0
95	6	55.0	1245	M	-	0
96	4	46.0	795	M	-	0
97	5	53.0	1190	M	-	0
98	6	53.0	1140	M	-	0
99	5	49.0	920	M	-	0
100	5	47.0	735	F	0	1