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Aquaculture Collaborative Research and Development Program (ACRDP) Fact Sheet

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Optimal Net Depth for Over-Wintering Bay d'Espoir, Newfoundland and Labrador, Aquaculture Salmonids

Summary

Bay d'Espoir, a main production area for the Newfoundland salmonid aquaculture industry on the south coast of the island, faces challenges associated with fish production in an extremely cold winter environment. In this region, surface freezing, under-ice culture and sub-lethal temperatures are common occurrences. The former Newfoundland Salmonid Growers Association (NSGA) sought to identify the necessary net depth for optimal salmonid aquaculture performance during winter periods. This study showed that the use of nets significantly deeper than 10 m for over-wintering of salmonids in high current areas in Bay d'Espoir may not be economically justifiable through increased growth or survival of 1st-year salmonids, however, net depths of up to 15 m may be useful for improving the economic performance of 2nd-year salmonids by increasing the likelihood of survival.

Introduction

Newfoundland salmonid growers have demonstrated significant aquaculture production capability in the temperate Northwest Atlantic environment of Bay d'Espoir. In a comparative sense, this aquaculture opportunity is unique for two main reasons. First, by having the largest freshwater inflow of any small Newfoundland Bay, much of the inner fjord freezes over during the winter such that under-ice cage culture becomes an expected component of the annual production cycle. Second, even on the ice free sites of the outer fjord, the cold Labrador current exerts considerable influence and subjects the coastal zone to winter water temperatures that can fall below the lower lethal limit for Atlantic salmon (–0.7°C). This makes for less than optimal production conditions since, under low water-temperature conditions, the salmonids exhibit little-to-no growth for three to four months of the year. The typical production cycle in this region spans 32 months, requiring at least one overwintering season.

These local environmental extremes prompted the former Newfoundland Salmonid Growers Association (NSGA) to seek an answer to the question: *What is the necessary net depth for optimal salmonid aquaculture performance during winter periods when sub-zero water temperatures may create sub-optimal on-growing conditions?* It was hypothesized that, given sufficient aquaculture net depth, healthy salmonids will choose a position in the water column that minimizes physiologically difficult conditions associated with temperature and/or salinity. However, from an economic point of view, every additional meter of depth added to a salmonid cage bears an incremental cost factor that must be balanced against improvements in production efficiency.

This fact sheet describes the results of a research project undertaken in 2001-2002 to determine the optimal net depth for over-wintering of Bay d'Espoir aquaculture salmonids.

Methods

The study location in the Matchums (Figure 1) is an area known to experience water temperatures that can be lethal to salmonids (-0.70°C). Except for an intermittent stream entering the ocean approximately one kilometre away, that occasionally causes some freshwater layering in the upper water column, the Matchums site typically experiences full-salinity (32 ppt) sea water.

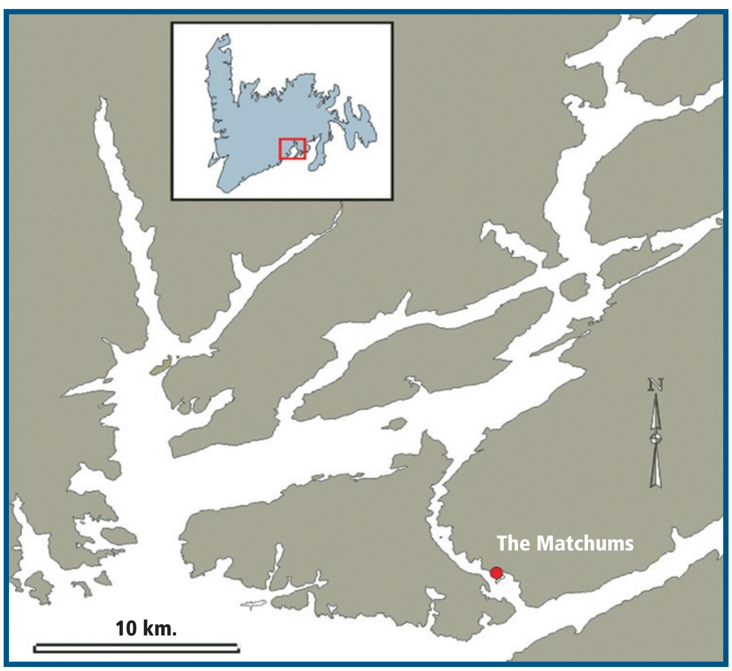

Figure 1.
Bay d'Espoir study area and the Matchums site location.

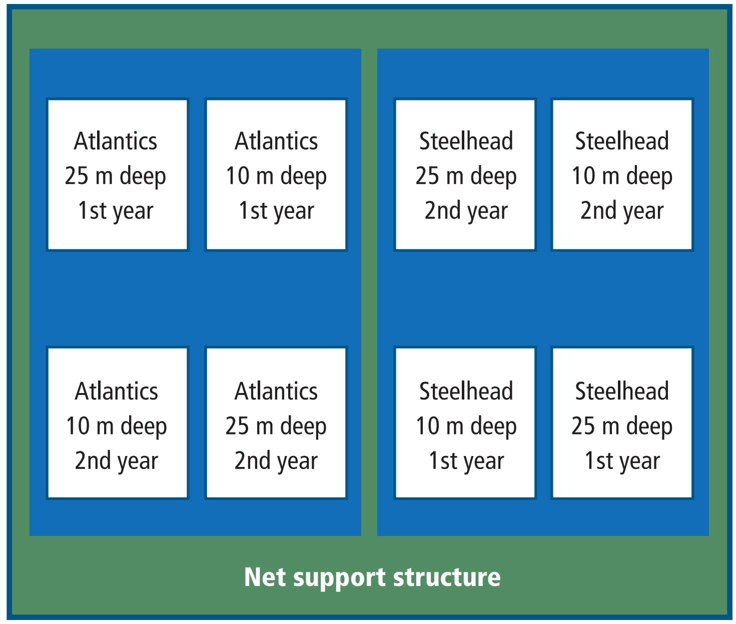

Figure 2.
Experimental design to evaluate optimal cage depth for overwintering of salmonids in Bay d'Espoir.

A cage array of eight, 7 m x 7 m nets was installed in an area with an average water depth of 45 m. Inventory groups of first and second year Atlantic salmon (*Salmo salar*) and steelhead trout (*Oncorhynchus mykiss*) were stocked into 10 and 25 m deep nets according to the cage array as per Figure 2.

The main performance indicator for this experiment was mortality. Odds-ratio analyses of survival were conducted by species with both year-classes combined. Secondary performance indicators included change in salmon and trout biomass, food conversion ratios (FCR) and performance index (increase in total biomass percent relative to FCR). Blood chemistry measures of physiological status were also incorporated into the full analysis. Fish position in the cages was monitored using diver observation and 30 tagged (Data Storage Tag to monitor depth, salinity and temperature) fish. This fact sheet focuses primarily on growth, survival and positioning in the water column.

Results

Change in Biomass

Analyses of weight and biomass changes were limited to comparisons between start and end weights for each species and year class (Table 1). Because a typical ongrowing cycle in Bay d'Espoir takes place over a 20-month period, at any given time there are two year-classes of salmonids in the marine phase of the production cycle. In this study, the 1st-year fish were from the 2000 year class; 2nd-year fish were from the 1999 year class.

Table 1.

Evaluation of normality and homogeneity of variance between initial and final salmonid weights.

Species	Year Class (m)	Net Depth	Sample Normality (p values)		Homogeneity of Variance (Levene): p =
			Start	End	
	1999	10	0.859	0.695	0.531
Salmon		25	0.315	0.952	0.078
	2000	10	0.859	0.823	0.776
		25	0.859	0.287	0.770
	1999	10	0.108	0.304	0.233
Trout		25	0.193	0.002	0.384
	2000	10	0.013	0.084	0.849
		25	0.223	0.911	0.271

The key over-wintering biomass changes and survival results are presented in Tables 2 and 3 where the shaded cells represent significant differences between start and end weights. The 2nd-year fish exhibited no change in biomass over the experimental period; all groups recorded lower weight, with the salmon in 25 m depth nets showing a significant reduction in biomass (Table 2). All first-year salmon and the first-year trout with the 10 m nets increased in biomass over the winter period; the same was not observed with the first year trout held in 25 m nets where a loss of biomass was observed.

Table 2.

Biomass changes during the Matchums over-wintering experiment.

Species	Year Class	Net Depth (m)	Biomass (kg)			Significance
			Start	End	Change	p (1-tail t)*
	1999	10	2948.6	2151.3	-797.3	0.059
Salmon		25	8460.3	5692.4	-2767.9	0.006
	2000	10	1644.3	1923.0	278.7	0.003
		25	4113.0	5209.9	1096.9	<0.001
	1999	10	3870.3	2644.4	-1225.9	0.071
Trout		25	10341.4	8306.9	-2034.5	0.202
	2000	10	2776.4	2906.2	129.8	<0.001
		25	7133.6	6548.3	-585.3	0.006

* Shaded cells on right represent significant differences between start and end weights.

Table 3.

Mantel – Haenszel odds-ratio tests for differences in survival potential for Atlantic salmon and steelhead trout in 10 m and 25 m deep aquaculture nets.

Species	Year Class	Net Depth (m)	End Salmonid Inventory Data Survival			Odds-Ratio Statistics		
			Dead	Alive	(%)	MH ratio	Chi-square	p <
	1999	10	339	661	66			
Salmon		25	696	2195	76	1.65	2.174	0.00001
	2000	10	23	1777	99			
		25	28	4472	99			
	1999	10	906	1094	55			
Trout		25	1469	3531	71	1.51	98.85	0.00001
	2000	10	409	1591	80			
		25	999	4001	80			

Survival

Odds-ratio tests confirm a significant difference in survival potential between the 10 m and 25 m nets for both salmon and steelhead when both year classes are combined (Table 3). Salmon in a 10 m deep net were 1.65 times as likely to die during the winter as salmon in a 25 m deep net; for steelhead, the odds-ratio is 1.51. However, survival percentages show that this difference is attributable entirely to the survival of 2nd-year fish for both species. Within the 1st-year class for both species, survival was the same, regardless of net depth. Survival was slightly improved in the 2nd-year class with the deeper nets. However, it should be noted that any genetic differences between year classes were not examined in this study.

Most losses occurred among 2nd-year steelhead where mortality was 29% and 45% in the 25 m and 10 m nets, respectively. These levels of mortality were experienced by mid-February. Many of the moribund fish expelled eggs when handled and examination by a veterinarian confirmed that 18 of out 20 moribund specimens were mature. Blood chemistry revealed that mortality among the moribund 2nd-year steelhead was preceded by osmoregulatory distress, likely due to the maturation process. Blood cortisol and glucose levels showed the same pattern as blood osmolality. Due to the high levels of mortality, the second year trout were harvested prior to termination of the experiment.

Depth Preference

Atlantic salmon spent most of their time (i.e., 86% of depth records) at ≤4.0 m in the water column (Figure 3). Steelhead showed somewhat less affinity for these shallower depths but still tended to remain above the 10 m depth limit.

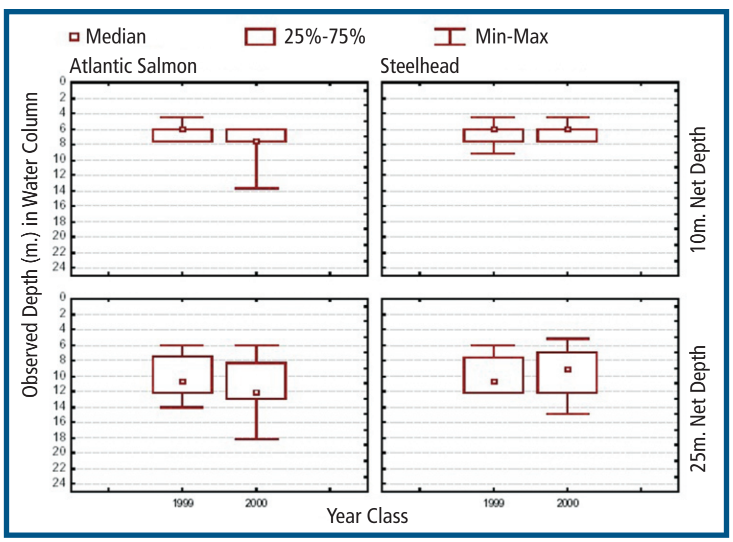

Figure 3.
Diver observations of vertical distribution of most of the fish in the water column.

Conclusions

Recommendations to the Bay d'Espoir salmonid aquaculture industry as a result of this research are:

- Use of nets of significantly >10 m for over-wintering of salmonids in high current areas in Bay d'Espoir may not be economically justifiable for 1st-year salmonids. Net depths of up to 15 m may be useful for improving the economic performance of 2nd-year salmonids but only if maturation is controlled and sources of physiological stress can be identified and remedied; and,
- The Bay d'Espoir salmonid aquaculture industry should investigate water-column use by salmonids during warm summer months to determine if nets of 15 m depth have any advantage over 10 m nets during the normal growing season.

This ACRDP project (N-01-06-003) was a collaborative effort among the Department of Fisheries and Oceans (DFO Science), the former Newfoundland Salmon Growers Association and the Newfoundland and Labrador Department of Fisheries and Aquaculture.

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For further information on this and other ACRDP projects, visit:
www.dfo-mpo.gc.ca/science/aquaculture/acrdp-pcrda/nfld/N-01-06-003_e.htm

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