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The Effect of Photoperiod on Growth and Maturation of Atlantic Salmon *(Salmo salar)* in the Bay of Fundy. Project of the Aquaculture Collaborative Research and Development Program

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ABSTRACT

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In 2001, a study on the effect of photoperiod on growth and early maturation was initiated on a commercial salmon farm in southwestern New Brunswick. Three cages (70-m diameter circles) had lights turned on November 21. A second set of three cages had lights turned on February 15, 2002. Lights were left on 24 h per day. All lights were turned off on May 31, 2002. Six unlit cages served as controls.

Fish were measured in the cages with a synchronized dual video camera. These measurements corresponded with the initiation of extended light, 1 mo following and at the end of the light regime. A preliminary sample of the fish was taken in July 2002 to collect growth and maturity data based on the gonadosomatic index (GSI). Beginning in August 2002 through February 2003, length, weight and maturity data were collected during harvest from two Xactic® tanks per cage. Additional maturation data were collected from a second site that initiated 24-h light in October 2001.

During the first month, specific growth rates decreased in the November lit cages. By the end of May, November lit cages showed significantly higher growth rates from the control cages. On site one, 21.5% of the control cages matured, 11.1% of the February lit cages and only 1.1% of the November lit cages. On the second site, maturation rates were 17.5% of the control cages and 5.0% of the October lit cages.

RESUME

Harmon, P.R., **B.D.** Glebe and R.H. Peterson. 2003. The effect of photoperiod on growth and maturation of Atlantic salmon *(Salmo salar)* in the Bay of Fundy. Project of the Aquaculture Collaborative Research and Development Program. Can. Tech. Rep. Fish. Aquat. Sci. 2458: iv + 16 p.

Une etude sur 1'effet de la photoperiode sur la croissance et la maturation prematuree du saumon atlantique fut initiee a un site commerciale salmonicole dans le sud-ouest du Nouveau-Brunswick en 2001. Des lampes furent allumees a une serie de trois cages (Cercles Polaires de 70m) le 21 Novembre et une deuxieme serie, le 15 fevrier, 2002. Les lampes furent allumees pour une duree de 24 heures pas jour et furent toutes eteintes le 31 Mai, 2002. Six cages non eclairees furent utilisees comme temoin.

Les poissons furent mesures a l'interieur des cages avec une camera video synchronizee double. Ces mesures correspondent avec l'initiation de la periode de lumiere prolonge, un mois apres le debut et a la fin. Un echantillon preliminaire fut pris en juillet 2002 pour recueillir des donnees sur la croissance et la maturation fondee sur l'indice gonadosomatique (IGS). Debutant en aout 2002 jusqu'en fevrier 2003, les donnees sur la croissance et la maturation furent recueillis lors de la recolte a partir de deux bassins Xactic® par cage. Des donnees additionnelles sur la maturation furent recueillis a un deuxieme site qui a initie une periode lumineuse de 24 heures en octobre 2001.

Lors du premier mois, le taux de croissance specifique a diminue dans les cages avec un periode lumineuse initie en novembre. Par la fin du mois de mai, ces cages ont demontre un taux de croissance significativement plus eleve par rapport aux cages temoins. Au premier site 21.5% des cages temoins ont atteint la maturite, 11.1% des cages initiees en fevrier et seulement 1.1 % des cages initiees en novembre. Au deuxieme site, le taux de maturation etait de 17.5% des cages temoins et de 5.0% des cages avec une periode lumineuse initiee en octobre.

INTRODUCTION

Early maturation in market fish is affecting greater than 30% of fish in some sea cages in southwestern New Brunswick. As a result, fish are downgraded, resulting in a loss of market value. As well, the stress of maturing in seawater leads to susceptibility to disease and car, result in further financial loss. The stress is compounded by the problem that early maturation may result in handling of the fish to remove the mature individuals.

The first commercial salmon aquaculture in the Bay of Fundy in New Brunswick began in 1978 at Deer Island. The incidence of maturation as grilse was less than 1 (Sutterlin et al. 1981). A decade later, Henderson (1988) documented the percentage maturing as grilse from 1^{+} smolts to be 6.9%. In the mid-1990s, Peterson et al. (2001), looking at three cages on each of 20 farms, found a total of 4.2% matures.

Earlier lab work (Saunders and Haiuion 1988) demonstrated extended daylength could increase postsmit growth in seawater. This study evaluates lighting as a method to increase growth and decrease early maturation. Taranger et al. (1991) showed extended daylength could decrease maturation.

MATERIALS AND METHODS

CAGES AND LIGHTS

The experimental cage site was located in southwestern New Brunswick (45 °N, 67°W). The cage site involved contained 12, 70-m circles (Fig.1). Three cages had lights turned on November 21, 2001. A second set of three cages had lights turned on February 15, 2002. Two 400-W Seebrite® lights simulating the natural light spectrum were placed in each cage. These lights, 15 ft from the surface, had a 24-foot separation. Lights were left on 24 h per day during the experiment. All lights were turned off on May 31, 2002. The remaining six cages were used as controls. This information is summarized in Table 1.

Data were also collected from a second cage site, which used 50-m circles. Two cages had lights turned on October 31, 2002. Two Seebrite® lights were used in each cage. All lights were turned off May 31, 2002. Another two cages were used as controls.

CAGE OBSERVATIONS

A synchronized dual video camera (Steeves et al. 1998) was lowered into each cage, and the fish were videotaped at each of five depths - 1, 2, 3, 4 and 5 m. Twenty fish were measured from each depth, resulting in a total of 100 fish being sampled per cage. From these videotapes, fish size was estimated by image analysis. Fish were measured on three occasions. The initial measurement was made on November 15, 2001, prior to lights being turned on. The second measurement was made December 21, 2001, after the lights had been on 1 mo. The final measurement was made on May 29, 2002, to coincide with the lights being turned off.

A conductivity temperature depth (CTD) profiler, Model 25, manufactured by Seabird Electronics, was used to measure the light intensity at three points around the edge of the three November lit cages. It was also used to measure light intensity at two points around three control cages z, each point readings were taken every 0.25 m to a maximum depth of 3.0-4.5 rn, depending on the cast. These measurements were recorded after dark on the evening of December 6, 2001.

SPECIFIC GROWTH RATES

Instantaneous specific growth rate expresses the rate of growth as percent per day averaged over a specific period of time. It is calculated as follows:

$$G = [(1nW_t - \ln W_0 it]*100,$$

where lnW; is the natural logarithim of the weight after time = t(usually days), $1nW_0$ is the natural log of the initial weight, t is the time period over which the estimate of growth rate is described, and G is the specific growth rate (Peterson et al. 2001).

HARVESTING

Beginning on July 12, 2002, a preliminary harvest sample was taken. One Xactic® tank was sampled from each cage. The following were recorded for each fish: sex, round weight, fork length, girth, dressed weight, mean fat content, gonad weight, deformities (scoliosis and jaw deformities) and head shape (elongation and kype). Muscle lipid levels were measured with a Torry fatmeter, model 692-CDF, calibrated for Salmon-1, Salmon-2, Salmon-3 and Salmon-4. The gonadosomatic index (GSI) was calculated by dividing 100 x the gonad weight by the body weight (Nikolsky 1963).

Beginning on August 12, 2002, coinciding with the harvesting of cages, a second set of samples was collected. Two Xactic® tanks were taken from different harvests of each cage. The following were recorded for each fish: length, weight, sex, maturity and deformities. The last sample was collected on February 6, 2003. The number of fish per tank ranged from 91-153.

On the second site, samples were taken in the lit cages on August 19, 2002. The control cages were sampled on September 4, 2002. One Xactic® tank was sampled from each cage. The number of fish per tank ranged from 98-100. The following were recorded for each: weight, sex and maturity.

RESULTS

LIGHT

The average light intensities for each cast and the mean for each cage are shown in Table 2. Cage means for the lit cages ranged from 2.386-3.131 lux. Cage means for the unlit cages ranged from 2.116 to 2.198 lux. These observations suggest that although light was escaping from each cage, it was of low intensity

GROWTH

The initial smolt sizes and camera measurements are entered in Table 3. Growth rates were calculated from smolt entry to November, November to December and December to May. The initial growth rate was based on the assumption all fish were placed in the water on April 15. Between April and November the smallest smolts had the fastest growth rates (>1.35). Smolts over 100 g had growth rates ranging from 1.16-1.22. After the lights had been on for 1 mo, the second camera measurement was taken. Cages A1 (November lit) and AS (control) had exactly the same initial growth rate of 1.19. However, after the lights had been on for 1 mo, the lit cage had approximately half the growth rate (0.365) of the control cage (0.611). Both cages Al and AS had smolts greater than 100 g. However, when we look at the two November lit cages with smolts less than 60 g, their growth rates are now comparable to the control cages. When the final camera measurement was made at the end of May when the lights were turned off, the November lit cages had the highest growth rates. November lit cages had growth rates greater than 0.32, while the control cages had growth rates less than 0.29.

The final two growth measurements were from fish sampled in the processing plant in July and again from August through February. These data and growth rates, according to sex and maturity, are shown in Table 4. Small sample sizes (n=2-9) in three groups have resulted in negative growth rates. This is felt to be a sampling artifact. In July, mature fish are growing at a faster rate than immature. But, by the time the fish are harvested, this has reversed, with matures growing very slowly through the last time period.

MATURATION

An estimate of maturation was made from a preliminary harvest sample taken from site one in July (Table **5). A** total of 821 fish was examined at the processing plant during 12 trips. GSI is shown in Table 6. Males with a GSI of 0.2 or greater and females with 0.3 or greater were considered mature (Thorpe 1994). GSI estimates, when averaged for each treatment, were consistently higher than the actual maturation rates from the harvest data. Based on the data, one could expect GSI to overestimate. This would be affected by different sex ratios in the sample.

Starting in August, harvest data were collected at site one. By this point, maturation could be determined by visual observation. These data are summarized in Table 7. We have calculated the percent mature fish in two samples per cage to arrive at the percent for the cage. A total of 2716 fish was examined at the processing plant during a total of 24 trips. Female fish outnumbered males in the samples (56.7% of all fish being females). The data show increasing percentage of females with increasing smolt size and a preponderance of males in smolts less than 60 g. Forty-gram smolts were 78.2% males, 50-g smolts were 55.5% males and 58-g smolts were 57.1% males. The largest smolts in the study were 123 g. They were 66.7% female (33.3% male).

Figure 2 illustrates the grilse production in the unlit and lit cages. Control males were 47.0% mature, whereas control females were only 9% mature. The overall percentage of matures in the control cages was 21.5%. In the February lit cages, males were 21.5% mature and females were 3.3% mature. The overall percentage of matures in the February lit cages was 11.1 %. In the November lit cages, males were 2.1 % with no mature females. The overall percentage of matures in the November lit cages was 1.1 %.

During August and September, harvest data were provided from site two. These data are summarized in Table 8. A total of 397 fish was examined at the processing plant. Figure 2 illustrates the grilse production in the unlit and lit cages. Control males were 22.5% mature; whereas control females were only 3% mature. The overall percentage of matures in the control cages was 17.5%. In the lit cages, males were 8.5% mature and females were 1.0% mature. The overall percentage of matures in the October lit cages was 5.0%.

DEFORMITIES

Five types of deformity were recognized in batches of fish sampled at the processing plant: a lower jaw deformity where the lower jaw is bent downward to varying degrees; an upper jaw deformity where the upper jaw is shortened, giving the fish a "bulldog" appearance; spinal curvature (scoliosis or lordosis); compressed spinal cord, giving the fish a stubby appearance; and a gill deformity where some of the operculum is missing (Peterson et al. 2001)

For this exercise fish were combined from the preliminary and harvest samples at site one. Of the 3537 fish inspected at the processing plant, a total of 147 had one or more of the above deformities (Table 9). The deformed lower jaw was most frequently encountered, with 69 fish (2% of all fish inspected).

LIPID

The lipid levels of sampled fish during the preliminary harvest are presented in Table 10. The average for the controls was 8.3%, for the February lit cages 7.6% and for the November lit cages 7.8%. However, these levels were not significantly different (S .05).

DISCUSSION

GROWTH

Exposure of Atlantic salmon parr in fresh water to increased daylength in the fall-early winter has been shown to significantly increase growth (Saunders et al. 1987). The next step was to see if increased daylength in the fall increased postsmolt growth in seawater. This was accomplished in lab trials at the St. Andrews Biological Station (Saunders and Harmon 1988). The present study provides further evidence of significantly increased growth by the end of May, and that in the first month following the introduction of continuous light, the growth rates decreased when compared to the controls. In Norway, Oppedal et al. (1997) reported no significant differences in growth between the controls and fish on continuous light in the first 11 wk. However, Oppedal et al. (2003) showed a depression in feed consumption during the first 6-8 wk after onset of continuous light. Taranger et al. (1995) showed appetite and growth decreased during a period of approximately 2 mo following the introduction of continuous light in seawater. Endal et al. (2000) reported a 48-52% reduction in specific growth rate during the subsequent 6 wk following the initiation of continuous additional light.

Table 11 summarizes fish weights normalized to a smolt size of 88.6 g. This is the mean entry weight at seawater entry in this study. In July, maturing control fish were considerably larger than immatures. They were probably heavier in December as well. The differences in weights of maturing and immature fish in lit cages were negligible in July. Matures were smaller and immatures heavier than control counterparts. Control immatures overtook maturing fish in early September. Matures in lit cages probably lost over 1 kg in weight in December-January.

Saunders et al. (1989) suggest artificially long photoperiod in fresh water is phase shifting the endogenous smolting rhythm and directly stimulating growth. In seawater, as well, it has been suggested that growth enhancement under continuous light is either due to a photoperiodic alteration of seasonal growth patterns or direct photoperiod stimulation of growth (Saunders and Harmon 1988; Hansen et al. 1992).

MATURATION

As early as 1982, DeVlaming et al. (1982) concluded that GSI is not an accurate indicator of gonadal activity. However, his work was with the fluffy sculpin *(Oligocottus snyderi)* and the inland silversides *(Menidia beryllina).* In his discussion he states, 'While the GSI may be appropriate for some species it is our contention that this index should not be applied without validation." For Atlantic salmon, GSI provides a trend but cannot be used to paint an exact picture of maturation. Based on our results, with more appropriate critical GSI cut-offs, a closer estimate of maturation for Atlantic salmon aquaculture in the Bay of Fundy could be developed.

Increased daylength in the fall significantly lowered maturation. Taranger et al. (1995) demonstrated the proportions of grilse were 21 and 26% under natural light compared to 9 and 11 % in groups exposed to continuous additional light. The continuous additional light was from January until May. An even lower percentage of grilse was found in this experiment. The earlier initiation of continuous light may account for this.

On average, increased daylength in February had a limited effect on maturation (11.1 %) and an unpredictable outcome with a range of 2.0-19.4%. The fish in the cage with 19.4% maturation were from a different hatchery source and may represent a difference in genetics and/or environmental manipulation.

Duston and Saunders (1992) have suggested a "decision period" exists based on energy reserves for sexual maturation. Taranger et al. (1999) have suggested that the effect of continuous light alters the positioning of the "critical period" and therefore reduces the incidence of maturation.

The cost of purchasing, wiring and operating the lights was less than $5,000 per cage. The savings gained per cage (70 m) was greater than $100,000 based on the November results. This calculation is based on differences in harvest weights of mature and immature salmon at a loss of approximately 1-2 kg per fish. At 15,000 fish per cage, approximately 25,000 kg have been lost. At a market price of $4.00, the loss would equal $100,000. This does not take into account downgrading due to poor flesh quality.

DEFORMITIES

All deformities, except the gill defoiuiity, result from some sort of skeletal deformity (Peterson et al. 2001). Insufficient oxygen supply during critical stages of skeletal formation has been shown to produce some of these deformities (Alderdice et al. 1958). Heavy metal and some pesticides may also act as teratogens (von Westernhagen 1988). Whether this is the case here is not known. Compressed spinal cord has been suggested to be possibly due to infection (Kvellestad et al. 2000) after transfer to cages.

CONCLUSIONS

- Increased daylength in the fall causes a growth drop for at least 4 wk, significantly increases growth by the end of May as compared to control immatures, and significantly lowers maturation rates.
- Increased daylength in February on average has a limited effect on maturation (11. 1%) and an unpredictable outcome (2.0 - 19.4%).
- The cost of purchasing, wiring and operating the lights is <$5,000 per cage; the savings gained per cage (70 m) is >$100,000 based on these results

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Table 1. Summary of cage site one information. End date refers to when lights were turned off.

Start/lights	Cages, 70-m	# lights	Light depth	Power	Day period	End date
November	Al, A3, B3	2 @ 400 W each	15'	240 V	24 h	May 31/02
February	B1, B2, A2	2 @ 400 W each	15'	240 V	24 h	May 31/02
Controls	B5, B6, A5	N/A	N/A	N/A	N/A	May 31/02

Table 2. Light intensities measured at the edge of the cages on December 6, 2001. Cages A 1, A3 and B3 are November lit; cages A5, **B5** and B6 are control.

Cage #	Cast #	Mean lux	Cage mean
A3	0	3.365	
	1	3.178	
	2	2.851	3.131
B3	3	2.573	
	4	2.535	
	5	2.480	2.529
Al	6	2.527	
	7	2.375	
	8	2.257	2.386
A5	9	2.144	
	10	2.150	2.147
B6	11	2.062	
	12	2.170	2.116
B5	13	2.173	
	14	2.222	2.198

Table 3. Growth rates (G) from smolt introduction (April) to lights being turned off in May.

Cage	Treatment	Smolt wt (g)	Nov. wt (g)	G (smolt-Nov)	Dec. wt	G (Nov-Dec)	May wt (g)	G (Dec-May)
Al	Nov. Lit	123	1586	1.19	1809	0.365	3190	0.357
A3	Nov. Lit	40	732	1.36	966	0.770	1810	0.395
B3	Nov. Lit	58	1145	1.39	1496	0.743	2500	0.323
A2	Feb. Lit	88					2550	
B2	Feb. Lit	50					2420	
B 1	Feb. Lit	94					2790	
A4	Control	95					2690	
A5	Control	103	1326	1.19	1652	0.611	2600	0.285
A6	Control	107					2340	
B4	Control	89					2490	
B5	Control	103	1389	1.22	1816	0.744	2840	0.281
B6	Control	113	1340	1.16	1762	0.760	2540	0.230

Table 4. Growth rates (G) from May through harvest broken down by sex and maturity. MM = mature males; IM = immature males; MF = mature females; IF = immature females.

		July weight				G May-July)				Ilarvest weight				Ilarvest				
Cage	Treatment	MM	IM	MF	IF	MM	IM	MF	IF	MM	IM	M	IF	Date	MM	IM	MI	I. - 1
Al	Nov. Lit	3394	3668		3585	0.132	0.297		0.248	5960	6080		6030	16.10.02	0.587	0.543		0.559
A3	Nov. Lit		2401		2513		0.601		0.698	2870	4050		4160	04.02.03		0.256		0.247
B3	Nov. Lit	3320	3165		3203	0.604	0.502		0.527	2990	5690		5730	06.01.03	-0.06	0.335		0.332
A2	Feb. Lit	3469	3186	3061	3164	0.655	0.473	0.389	0.459	3880	5930	3470	6150	27.01.03	0.057	0.317	0.064	0.339
B2	Feb. Lit	2574	2781	1886	2834	0.131	0.296	*-0.53*	0.336	2730	5670	4410	5480	16.01.03	0.032	0.385	0.459	0.356
B1	Feb. Lit	3629	3340		3393	0.559	0.383		0.416	3970	5400	2960	5240	19.12.02	0.057	0.306		0.277
A4	Control	3756	3047	3167	2780	0.710	0.265	0.347	0.070	4580	3950	3880	3940	09.09.02	0.354	0.463	0.363	0.623
A5	Control	3531	3386	3588	2846	0.651	0.562	0.685	0.192	4210	3450	4080	3360	12.08.02	0.628	0.067	0.459	0.593
A6	Control	3714	2710	2973	2610	0.983	0.312	0.509	0.232	4200	4300	3670	4390	27.09.02	0.166	0.624	0.285	0.703
B4	Control	3559	2524	3989	2577	0.76	0.029	1.003	0.073	3960	4500	4090	4780	09.10.02	0.124	0.672	0.103	0.718
B5	Control	3927	2449	3899	2893	0.69	-0.316	0.674	0.039	4170	3510	4360	3590	24.08.02	0.150	0.900	0.279	0.540
B6	Control	3597	2890	4346	2942	0.74	0.274	1.143	0.313	4500	4280	4060	4300	16.09.02	0.356	0.623	-0.108	0.602

Table 5. Preliminary harvest sample taken in July 2002. Round weights are in kilograms; gonad weights are in grams.

Cage	N female	N male	` o female	fir. male	N	Treatment	Avg. female round wt	Avg. male round wt	Avg. female gonad wt	Avg. male gonad wt
A6	47	25	65	35	72	unlit	2.6	3.4	5.4	17.3
A4	32	33	49	51	65	unlit	2.8	3.5	**6.5**	15.0
A5	45	29	61	39	74	unlit	3.0	3.5	8.0	12.7
B 6	43	27	61	39	70	unlit	3.2	3.3	8.2	15.4
B5	38	26	59	41	64	unlit	*3.1*	*3.2*	*7.3*	10.1
B4	50	19	72	28	69	unlit	2.6	2.8	4.8	5.7
unlit total	255	159	62	38	414					
Al	40	30	57	43	70	Nov. lit	3.6	3.6	5.3	4.4
A3	12	57	17	83	69	Nov. lit	2.5	2.4	3.3	1.8
B3	27	42	39	61	69	Nov. lit	3.2	3.2	4.6	3.0
Nov. total	79	129	38	62	208					
131	44	26	63	37	70	Feb. lit	3.4	3.4	6.4	17.8
A2	33	37	47	53	70	Feb. lit	3.2	3.2	6.9	10.6
B2	22	37	37	63	59	Feb. lit	2.8	2.8	4.1	4.5
F'eb.total	99	100	50	50	199					

Table 6. A comparison of maturation rates from the preliminary and harvest data.

Cage	Treatment	% mature (GSI)	c mature (actual)	% mature male (GSI)	% mature male (actual)	% mature female (GSI)	% mature female (actual)
A6	Control	29.2	33.6	64.0	66.2	10.6	19.1
A4	Control	36.9	13.8	63.6	40.0	4.2	4.2
A5	Control	36.5	26.7	55.2	58.5	24.4	13.3
B6	Control	34.3	22.4	55.6	45.4	20.9	8.0
B5	Control	32.8	22.4	53.8	44.0	18.4	8.8
B4	Control	8.7	9.9	26.3	28.0	2.0	0.6
Mean		29.7	21.5	53.1	47.0	13.4	9.0
SD		10.7	8.6	13.8	13.6	9.2	6.6
A2	February	17.1	19.4	21.6	36.3	12.1	3.7
B i	February	10.0	11.9	23.1	25.3	2.3	2.5
B2	February	8.5	2.0	10.8	2.8	4.5	1.1
Mean		11.9	11.1	18.5	21.5	6.3	2.4
SD		4.6	8.7	6.7	17.1	5.1	1.3
Al	November	4.3	0.5	10.0	1.6	0.0	0.0
A3	November	0.0	1.0	0.0	1.3	0.0	0.0
B3	November	1.4	1.9	2.3	3.3	0.0	0.0
Mean		1.9	1.1	4.1	2.1	0.0	0.0
SD		2.2	0.7	5.2	1.1	0.0	0.0

Table 7. Summary of harvest data for site one collected at the processing plant. Harvest size is in kilograms; gonad weights are in grams. MM = mature males; LM = immature males; MF = mature females; IF = immature females

Cage #	Treatment	Date	# Al	# MM	# IF	# MF	% MM	% MF	Tot % Mat	Smolt size	Harvest size
AS	Control	12.08.02	31	44	156	24	58.5	13.3	26.7	103	3.58
B5	Control	21.08.02	56	44	145	14	44.0	8.8	22.4	103	3.84
A4	Control	09.09.02	21	14	91	4	40.0	4.2	13.8	95	4.01
B6	Control	16.09.02	47	39	150	13	45.4	8.0	22.4	113	4.31
A6	Control	27.09.02	26	51	140	33	66.2	19.1	33.6	107	4.25
B4	Control	09.10.02	61	24	167	1	28.0	0.6	9.9	89	4.64
A1	Nov.	16.10.02	64	1	130	0	1.60	0.0	0.5	123	6.03
B1	Feb	19.12.02	62	21	115	3	25.3	2.5	11.9	94	5.12
B3	Nov.	06.0 .03	116	4	90	0	3.30	0.0	1.9	58	5.65
B2	Feb	16.01.03	108	3	88	1	2.80	1.1	2.0	50	5.53
A2	Feb	27.01.03	65	37	105	4	36.3	3.7	19.4	40	4.06
A3	Nov.	03.02.03	234	3	66	0	1.30	0.0	1.0	88	5.63

Table 8. Summary of harvest data for site two collected at the processing plant.

Cage	Lit/Unlit	%females	% grilse	% male mature	% female mature
3	Unlit	28.0	13.0	16.0	3.0
4	Unlit	29.0	22.0	29.0	3.0
	MEAN	28.5	17.5	22.5	3.0
	SD	0.5	3.0	**6.5**	0.0
12	Lit	48.0	3.0	6.0	0.0
11	Lit	46.0	7.0	11.0	2.0
	MEAN	47.0	**5.0**	**8.5**	1.0
	SD	1.0	2.0	2.5	1.0

Table 9. Summary of deformities from fish sampled from site one at processing plant.

Source	#	Lower jaw	Upper jaw	Spinal curvature	Compressed spinal	Gill
Preliminary	821	16	1	3	0	10
Harvest	2716	**53**	10	19	6	29
Total	3537	69	11	22	6	39
Percent	100	1.95	0.31	0.62	0.17	1.1

Table 10. Summary of percent lipid data from preliminary harvest.

Cage	Treatment	Mean	Median	Minimum	Maximum	**SD**
A6	Control	8.6	8.9	3.7	11.8	1.7
A4	Control	8.8	8.9	3.2	12.1	1.7
A5	Control	9.0	9.1	4.5	11.6	1.5
B6	Control	8.9	9.0	4.4	12.9	1.8
B5	Control	7.4	7.4	3.8	11	1.5
B4	Control	6.8	6.8	2.5	11	1.7
Mean		8.3				
SD		0.9				
A2	Feb.	7.9	8.0	2.8	12.1	1.7
B1	Feb.	6.6	6.3	4.5	9.9	1.3
B2	Feb.	8.3	8.2	4.4	12.5	1.7
Mean		7.6				
SD		0.9				
A1	Nov.	7.8	7.3	4.9	11.5	1.5
A3	Nov.	7.7	7.5	5.2	10.6	1.4
B3	Nov.	8.0	7.8	5.2	10.8	1.3
Mean		7.8				
SD		0.2				

Table 11. Summary of fish weights (grams) normalized to a smolt size of 88.6 g.

	Control				February Lights				November Lights			
Date	MM	IM	MF	IF	MM	IM	MF	IF	MM	IM	MF	IF
21.12.01	1527	1527	1527	1527	1527	1527	1527	1527	1527	1527	1527	1527
15.07.02	3681	2834	3660	2775	3224	3102	3130	3130	3038	3078		3100
12.08.02	4380	2891	4172	3274								
24.08.02	3902	4053	4099	3441								
09.09.02	4491	3684	4465	3940								
16.09.02	4610	4194	3404	4052								
27.09.02	4160	4506	4502	4662								
09.10.02	4086	5044	3733	5134								
16.10.02									5256	5109		5208
12.12.02					3514	5025	2723	4820				
06.01.03									2734	5540		5549
16.01.03					3417	6328	4945	6041				
27.01.03					3611	5271	3537	6072				
04.02.03									3646	5201		5146

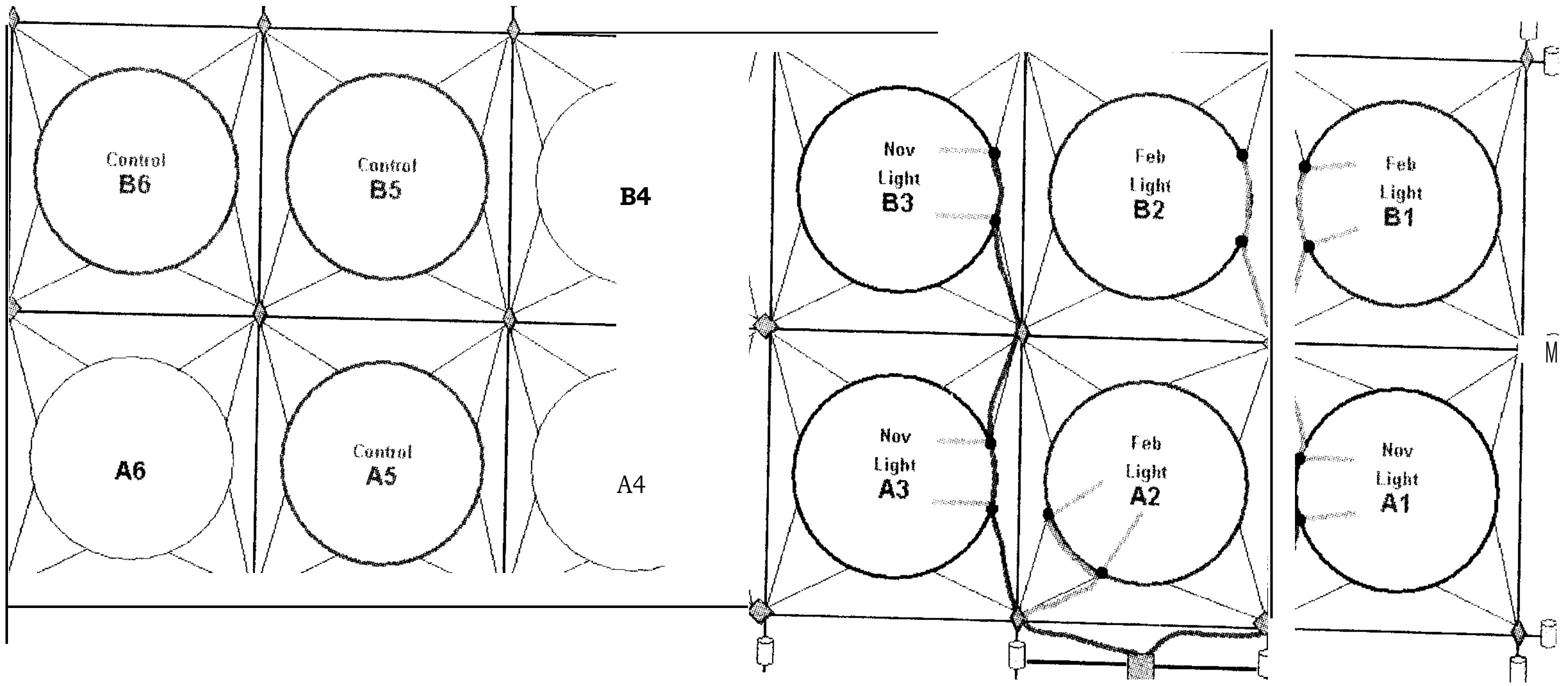

Fig. 1. Schematic of cage site one; cage site diameters are 70 m.

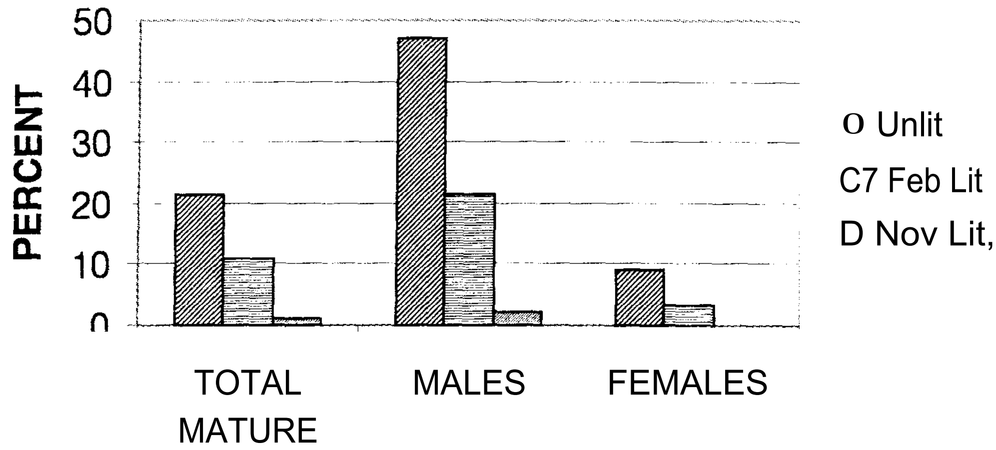

Fig. 2. Percentage of grilse, mature males and females in harvest samples from unlit, November and February lighted cages on site 1.

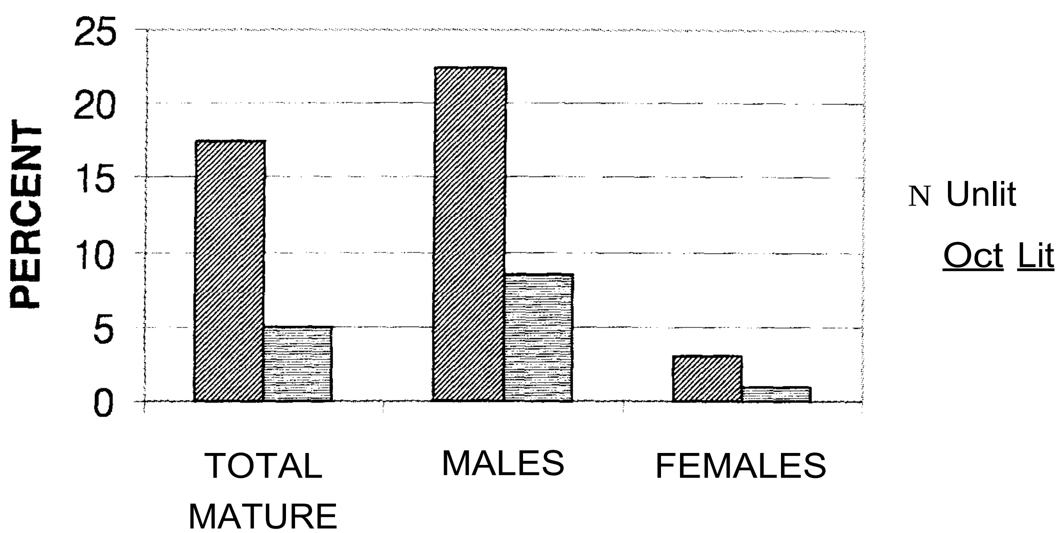

Fig. 3. Percentage of grilse, mature males and females in samples from unlit and lighted cages on site 2.