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by:

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ABSTRACT

Angled and control male and female Atlantic salmon collected from the headwaters of the Miramichi River, New Brunswick in the autumns of 1991 and 1992 were spawned at the Miramichi Salmonid Enhancement Centre. No significant differences in gamete viability (measured in terms of pre-hatch egg survival) were found between crosses of control and angled salmon, nor was there evidence of differences in survival to hatch or to first feeding for the resulting fry. These results, combined with adult survival and physiological data indicate that salmon subjected to late season catch-and-release angling can be expected to survive and recover rapidly with no adverse effects on their gametes or progeny.

RÉSUMÉ

Des saumons de l'Atlantique mâles et femelles capturés par la pêche à la ligne dans le bassin d'amont de la Miramichi aux automnes 1991 et 1992 ainsi que des individus témoins ont frayé au Centre de mise en valeur des salmonidés de la Miramichi. On n'a décelé aucune différence significative dans la viabilité des gamètes (qui se mesure par la survie des oeufs) entre les croisements des saumons témoins et des saumons capturés à la ligne; il n'y avait non plus aucune différence dans le taux de survie jusqu'à l'éclosion ou la première alimentation des alevins découlant du croisement. Ces résultats, ainsi que les données sur la survie des adultes et les données physiologiques, indiquent que les saumons soumis à uné capture (à la ligne) et une remise à l'eau en fin de saison peuvent survivre et récupérer rapidement sans que ceci ait des répercussions négatives sur leurs gamètes ou leur progéniture.

Introduction

The practice of catch-and-release is being actively promoted in recreational fisheries throughout North America as a means of protecting and conserving fish populations. A catch-and-release regulation for Atlantic salmon was introduced in Atlantic Canada in 1984. This regulation prohibits the retention of salmon over 63 cm in length in the recreational fisheries of insular Newfoundland, New Brunswick, Prince Edward Island, and Nova Scotia and is viewed as a means of enhancing the reproductive potential of salmon stocks by protecting the large, predominantly female salmon from harvest.

It is widely recognized that even catch-and-release fisheries affect the biology and production potential of fish stocks. Numerous studies have attempted to quantify the effects of catch-and-release practices. The majority of these have centred on estimating mortality rates, and the effect of environmental parameters, gear types, and angling practices on angling induced stress and mortality (Schill and Griffith, 1986; Dotson, 1982; Marnell and Hunsaker,1970; Wydoski, 1977; Ferguson and Tufts, 1992; Bendock and Alexandersdottir, 1993; Gjernes et al., 1993).

Studies of the effects of catch-and-release angling on Atlantic salmon are limited and have concentrated on determining hooking mortality rates in landlocked (Warner, 1976,1978,1979; Warner and Johnson, 1978) and sea-run salmon (Currie,1985). Little is known about the sub-lethal effects of catch-and-release angling. One of the potential sub-lethal effects of angling stress is a reduction in reproductive ability.

Stress, such as that associated with the exhaustive exercise experienced by a fish when angled, has been shown to have suppressive or inhibitory effects on reproductive functions. Although several studies have investigated the physiological effects of stress on reproductive processes in salmonids (Billard and Gillet, 1981; Pickering et al., 1987; Carragher et al., 1989; Pottinger and Pickering, 1990), few have tried to quantify these effects in terms of the ultimate measure of reproductive capability - ie. the production of viable offspring.

Campbell et al. (1992) investigated the effect of stress on rainbow trout, *Onchorynchus mykiss* under laboratory conditions. They found that exposing rainbow trout to repeated episodes of acute stress during gametogenesis did not significantly effect the survival of their eggs through to the eyed stage. However, hatching success and survival through to feeding were significantly lower for the progeny of stressed fish compared to the progeny from unstressed, control fish.

Petit (1977) compared the survival through to the eyed stage of eggs from female steelhead trout, *Onchorynchus mykiss*, angled early in the maturation cycle to those of control females and found no significant differences. He did not however, compare hatching success or survival through to feeding for the two groups.

The possibility that caught-and-released salmon, especially those caught late in the season when they are close to spawning, would have reduced gamete viability has been a subject of concern for salmon conservation groups when considering the implications of fall season extensions. This study addresses that concern by comparing the gamete viability from salmon exposed to angling stress late in the season to that of non-angled salmon collected during the same time period.

Materials and Methods

Salmon for the experiment were collected by seining from the barrier pool operated by the New Brunswick Department of Natural Resources and Energy (NBDNRE) on the North Branch of the Main Southwest Miramichi River near Juniper, New Brunswick (Figure 1) on October 11, 1991 and October 6, 1992. Water temperature on both dates was 5-6 °C. Control males and females were put directly from the seine into transportation tanks and transported to the Department of Fisheries and Oceans' Miramichi Salmonid Enhancement Centre (SEC) at South Esk, New Brunswick. In 1991, low numbers of salmon at the Juniper Barrier resulted in the capture of only 6 male salmon for use as controls (Table 1). The remaining 1991 controls (8 females and 10 males - Tables 1 & 5) were collected from the NBDNRE barrier on the Dungarvon River (Figure 1). In 1992, all controls (10 females and 10 males) were collected at the Juniper Barrier (Tables 3 & 7).

Salmon to be used for the "angled" group were placed in 1m x 0.75m x 3m holding boxes anchored in the river. Angling was simulated by removing salmon (8 males and 8 females in 1991, 10 of each sex in 1992) from the holding box and imbedding an artificial fly in their lower jaw. The salmon were then released into the pool where they were played to exhaustion (indicated by loss of equilibrium) on flyfishing gear by experienced anglers. The time that each salmon was played was recorded (Tables 2,4,6 & 8). When exhausted, the flies were removed from the salmon's jaw and the fish were tagged for identification, placed in transportation tanks and transported to the Miramichi SEC.

The salmon were spawned at the Miramichi SEC. The weights and lengths of each salmon were recorded just prior to spawning (Tables 1-8). The eggs from each female were divided into two roughly equal aliquots. One aliquot was fertilized by a control male and the other was fertilized by an angled male. In 1991, each angled male was used twice; once to fertilize an angled female and once to fertilize a control female (Table 2). Each control male was used only once to fertilize either an angled or a control female (Table 1). In 1992, both angled and control males were used twice (Tables 3 & 4). In both years the matings resulted in 4 crosses (treatments) containing 8 (1991) and 10 (1992) groups of eggs (observations) in each cross (treatment).

Eggs were incubated in trays held in troughs supplied with surface water at ambient temperature (0.5 °C). Egg losses were recorded weekly for each group over the incubation period until they were loaded into upwelling incubation boxes in preparation for hatching (April 25 both years). Initial egg numbers in each group were calculated when the eggs were fully eyed and robust in terms of their ability to withstand handling. A sample of 100 eggs was randomly picked from each egg group. These eggs were placed into a fine mesh net and excess water was allowed to drain. The eggs were then placed into a 25 ml. graduated cylinder containing a known volume of water. The volume of water displaced by the 100 egg sample was then used to calculate the number of eggs per ml. The total volume of all the eggs in the group was then measured and multiplied by the number of eggs per ml. to give the number of remaining eggs. Egg loss to date was then added to give the initial number of eggs in the group. Percent pre-hatch egg survival for each group (Tables 5-8) was calculated as follows:

$$\% \text{ Survival} = \frac{\text{Number of eggs remaining in each group on April 25}}{\text{Initial number of eggs in each group}} \times 100$$

These percentages were arc-sine transformed and compared between crosses using a one-way ANOVA.

It was not logistically possible to keep each group of fry separate after hatching. However, all the eggs from each cross were loaded into separate incubation boxes and upon hatching the fry from each of the four crosses were held separately and their survival to hatch and first feeding (calculated as a percentage of the total initial number of eggs for each cross) was recorded (Table 9).

Results and Discussion

As previously noted, it has been found that exposure of rainbow trout, *Onchorynchus mykiss*, to repeated episodes of acute stress (Campbell et al., 1992) or the stress of angling and release (Petit, 1977) has no significant effect on the pre-hatch survival of their eggs. The results of the present study indicate the same result for Atlantic salmon, *Salmo salar*, exposed to the stress of late season angling.

Pre-hatch egg survival (Tables 5-9) was not found to significantly differ ($P<0.05$) between egg groups in different crosses in either 1991 ($F_{3,28}=2.56$, $P=0.08$) or 1992 ($F_{3,36}=0.73$, $P=0.54$). Mean pre-hatch egg survivals were high and comparable to those of other salmon held at the Miramichi SEC.

The 1991 pre-hatch egg survivals did differ significantly at the $P<0.10$ level. One factor which affected this result was the poor egg survival observed for female AF7 (Table 6). Mean pre-hatch egg survival for angled female x angled male and angled female x control male crosses in 1991 (Table 9) are 2.9% higher (94.9% and 96.1% respectively) if egg survivals for female AF7 are not included. A second factor which may have compromised the results was potential genetic differences between the Juniper and Dungarvon salmon which may have resulted in differences in egg survivals. These two factors provided the impetus for repeating the study in

1992.

However, in contrast to the findings of Campbell et al. (1992) for rainbow trout, there was no indication that the progeny of salmon exposed to (angling) stress exhibited poorer than normal survival through to hatching or feed-up.

The stress encountered by the angled fish in the experiments was no doubt exacerbated by seining and handling in the holding boxes and subsequent tagging, transportation, and manual spawning and should therefore be considered a "worst case" scenario. Nevertheless, these results indicate that this late in the season, gametogenesis is far enough advanced that it is unaffected by such stress episodes. Furthermore, salmon exhibit excellent resilience to exposure to such stress at this time of year and in these cold water temperatures (5-6 °C). No mortalities occurred in the salmon (118 in total) used over the two years' experiments. Measurement of a series of physiological parameters (plasma and muscle metabolites and ions) conducted on both angled and control salmon in conjunction with the 1992 study showed that angled salmon fully recovered from the effects of angling stress in 4-8 hours (Booth et al., 1994). The effect that catch-and-release angling may have on mating or migratory behaviour has yet to be quantified and will be the subject of future studies; however, our results, combined with those of Booth et al. (1994), indicate that salmon subjected to catch-and-release angling in the late fall can be expected to survive and recover rapidly with no adverse effects on their gametes or progeny.

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Figure 1 - Location of collection sites for salmon used in the 1991 and 1992 studies of the effect of late season catch-and-release angling on gamete viability

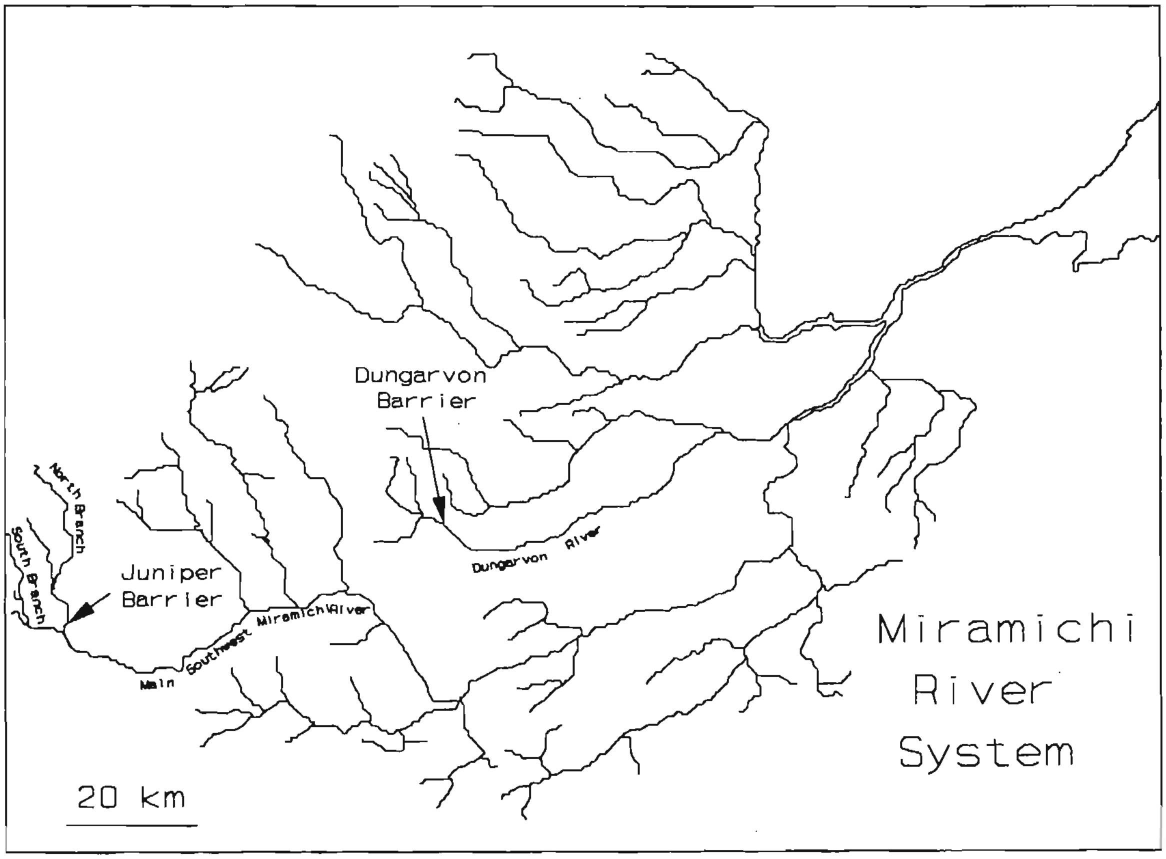

Table 1: Control males collected at the Juniper Barrier - October 11, 1991, and at the Dungarvon Barrier - September 17, 1991

ID Number	Time Played (min.sec)	Length (cm)	Weight (Kg.)	Age	First Spawning Date	Second Spawning Date	Control Female	Angled Female
CM1D*	0.00	55.2	1.20	3.1+	Oct. 19/91	----	CF1	
CM2D	0.00	56.8	1.35	2.1+	Oct. 19/91	----	CF2	
CM3D	0.00	54.5	1.34	3.1+	Oct. 19/91	----	CF3	
CM4D	0.00	51.5	0.96	2.1+	Oct. 22/91	----	CF4	
CM5D	0.00	53.5	1.09	3.1+	Oct. 22/91	----	CF5	
CM6D	0.00	50.5	0.98	2.1+	Oct. 22/91	----	CF6	
CM7D	0.00	57.0	1.36	3.1+	Oct. 22/91	----	CF7	
CM8D	0.00	56.0	1.35	?.1+	Oct. 22/91	----	CF8	
CM9J	0.00	49.0	0.86	2.1+	Oct. 22/91	----		AF6
CM10J	0.00	55.0	1.24	3.1+	Oct. 17/91	----		AF2
CM11J	0.00	51.2	1.18	2.1+	Oct. 17/91	----		AF4
CM12J	0.00	52.9	1.00	2.1+	Oct. 17/91	----		AF3
CM13J	0.00	52.2	1.10	2.1+	Oct. 19/91	----		AF5
CM14J	0.00	53.8	1.23	3.1+	Oct. 11/91	----		AF1
CM15D	0.00	49.5	1.00	3.1+	Oct. 22/91	----		AF7
CM16D	0.00	53.5	1.23	3.1+	Oct. 22/91	----		AF8

* - "D" = Dungarvon salmon; "J" = Juniper salmon

Table 2: Males angled at the Juniper Barrier - October 11, 1991

ID Number	Time Played (min.sec)	Length (cm)	Weight (Kg.)	Age	First Spawning Date	Second Spawning Date	Control Female	Angled Female
AM1	2.00	51.5	1.21	3.1+	Oct. 11/91	Oct. 22/91	CF5	AF1
AM2	3.30	51.5	1.04	2.1+	Oct. 17/91	Oct. 22/91	CF8	AF3
AM3	9.00	81.5	4.57	2.3,1+	Oct. 17/91	Oct. 22/91	CF4	AF4
AM4	8.00	56.0	1.13	3.1+	Oct. 17/91	Oct. 22/91	CF6	AF2
AM5	4.00	58.5	1.73	2.1+	Oct. 19/91	Oct. 19/91	CF1	AF5
AM6	7.00	54.0	1.27	2.1+	Oct. 19/91	Oct. 22/91	CF3	AF7
AM7	3.30	50.5	0.95	2.1+	Oct. 19/91	Oct. 19/91	CF2	AF6
AM8	9.00	56.5	1.25	2.1+	Oct. 22/91	Oct. 22/91	CF7	AF8

Table 3: Control males collected at the Juniper Barrier - October 6, 1992

ID Number	Time Played (min.sec)	Length (cm)	Weight (Kg.)	Age	Spawning Date	Control Female	Angled Female
CM1.92	0.00	80.0	4.3	N\A	Oct. 19/92	CF1.92	AF1.92
CM2.92	0.00	62.5	2.3	"	" " "	CF2.92	AF2.92
CM3.92	0.00	88.0	6.3	"	" " "	CF3.92	AF3.92
CM4.92	0.00	52.0	1.2	"	" " "	CF4.92	AF4.92
CM5.92	0.00	85.5	5.4	"	" " "	CF5.92	AF5.92
CM6.92	0.00	86.0	5.6	"	" " "	CF6.92	AF6.92
CM7.92	0.00	82.0	4.8	"	" " "	CF7.92	AF7.92
CM8.92	0.00	57.5	1.5	"	" " "	CF8.92	AF8.92
CM9.92	0.00	53.5	1.2	"	" " "	CF9.92	AF9.92
CM10.92	0.00	59.0	1.7	"	" " "	CF10.92	AF10.92

Table 4: Males angled at the Juniper Barrier - October 6, 1992

ID Number	Time Played (min.sec)	Length (cm)	Weight (Kg.)	Age	First Spawning Date	Control Female	Angled Female
AM1.92	6.00	58.5	1.6	N\A	Oct. 19/92	CF10.92	AF10.92
AM2.92	8.00	84.0	5.4	"	" " "	CF1.92	AF1.92
AM3.92	4.15	64.5	2.4	"	" " "	CF2.92	AF2.92
AM4.92	11.00	78.0	4.2	"	" " "	CF3.92	AF3.92
AM5.92	7.41	88.0	5.8	"	" " "	CF4.92	AF4.92
AM6.92	10.00	73.5	2.9	"	" " "	CF5.92	AF5.92
AM7.92	5.45	55.0	1.5	"	" " "	CF6.92	AF6.92
AM8.92	17.20	86.5	5.3	"	" " "	CF7.92	AF7.92
AM9.92	4.30	54.0	1.3	"	" " "	CF8.92	AF8.92
AM10.92	5.00	54.5	1.3	"	" " "	CF9.92	AF9.92

Table 5: Control females collected at the Dungarvon Barrier - September 17, 1991

								Angled Male			Control Male		
ID Number	Time Played (min.sec)	Length (cm)	Weight (Kg.)	Age	Spawning Date	Egg Diameter (mm)	Total Number of Eggs	Male ID Number	Initial Number of Eggs	% Pre-hatch Egg Survival*	Male ID Number	Number of Eggs	% Pre-hatch Egg Survival*
CF1	0.00	72.7	3.74	2.2+	Oct. 19/91	6.20	4,859	AM5	2,102	98.0	CM1D	2,757	88.2
CF2	0.00	68.2	3.02	3.2+	Oct. 19/91	6.10	4,341	AM7	1,926	99.7	CM2D	2,415	99.2
CF3	0.00	75.5	4.25	2.2+	Oct. 19/91	6.25	5,050	AM6	2,595	97.6	CM3D	2,455	95.0
CF4	0.00	88.0	6.89	4.2+	Oct. 22/91	6.75	9,297	AM3	4,820	98.7	CM4D	4,477	97.5
CF5	0.00	75.5	3.98	2.2+	Oct. 22/91	5.95	6,212	AM1	2,805	99.0	CM5D	3,407	97.8
CF6	0.00	73.0	5.77	N/A	Oct. 22/91	6.75	7,308	AM4	3,384	97.7	CM6D	3,924	98.9
CF7	0.00	91.0	6.66	3.4,2+	Oct. 22/91	7.00	5,383	AM8	2,731	98.3	CM7D	2,652	98.0
CF8	0.00	82.5	5.99	3.4.2+	Oct. 22/91	6.50	6,557	AM2	3,343	96.6	CM8D	3,214	98.2

Table 6: Females angled at the Juniper Barrier - October 11, 1991

								Angled Male			Control Male		
ID Number	Time Played (min.sec)	Length (cm)	Weight (Kg.)	Age	Spawning Date	Egg Diameter (mm)	Total Number of Eggs	Male ID Number	Initial Number of Eggs	% Pre-hatch Egg Survival*	Male ID Number	Number of Eggs	% Pre-hatch Egg Survival*
Af1	11.00	74.5	3.9	3.2+	Oct. 11/91	6.25	6,617	AM1	2,728	92.0	CM14J	3,889	92.0
AF2	8.00	78.0	5.06	2.2+	Oct. 17/91	6.10	6,265	AM4	3,419	95.6	CM10J	2,846	96.4
AF3	5.30	70.8	3.06	2.2+	Oct. 17/91	5.95	4,255	AM2	2,205	90.0	CM12J	2,050	93.9
AF4	10.00	71.3	3.57	2.2+	Oct. 17/91	6.00	5,678	AM3	2,984	98.7	CM11J	2,694	98.6
AF5	11.00	95.5	9.13	N/A	Oct. 19/91	6.45	14,272	AM5	4,364	96.0	CM13J	3,985	98.7
AF6	5.30	103.0	10.50	N/A	Oct. 22/91	6.00	14,025	AM7	6,59	95.9	CM9J	7,366	96.4
AF7	12.00	74.5	4.47	2.5+,2+,4+	Oct. 22/91	5.95	6,794	AM6	3,244	72.6	CM15D	3,550	72.8
AF8	10.00	75.6	4.51	N/A	Oct. 22/91	6.75	7,567	AM8	3,817	95.9	CM16D	3,750	96.9

Table 7: Control females collected at the Juniper Barrier - October 6, 1992

								Angled Male			Control Male		
ID Number	**Time Played (min.sec)**	**Length (cm)**	**Weight (Kg.)**	**Age**	**Spawning Date**	**Egg Diameter (mm)**	**Total Number of Eggs**	**Male ID Number**	**Initial Number of Eggs**	**% Pre-hatch Egg Survival***	**Male ID Number**	**Number of Eggs**	**% Pre-hatch Egg Survival***
CF1.92	0.00	75.0	4.2	N\A	Oct. 19/92	6.20	6,976	AM2.92	4,365	99.6	CM1.92	2,611	9.5
CF2.92	0.00	90.0	7.8	"	" " "	6.30	8,858	AM3.92	5,667	96.8	CM2.92	3,191	96.4
CF3.92	0.00	70.5	3.6	"	" " "	6.15	6,636	AM4.92	3,471	99.6	CM3.92	3,165	99.3
CF4.92	0.00	73.5	3.9	"	" " "	6.25	7,006	AM5.92	4,161	98.4	CM4.92	2,840	97.4
CF5.92	0.00	73.5	3.7	"	" " "	6.15	5,558	AM6.92	2,934	96.8	CM5.92	2,624	94.4
CF6.92	0.00	75.0	4.1	"	" " "	6.35	6,419	AM7.92	2,841	99.2	CM6.92	3,578	99.0
CF7.92	0.00	67.0	3.0	"	" " "	6.15	4,786	AM8.92	2,718	98.3	CM7.92	2,068	97.4
CF8.92	0.00	79.0	5.3	"	" " "	6.40	8,491	AM9.92	4,425	98.2	CM8.92	4,065	90.2
CF9.92	0.00	73.5	3.9	"	" " "	6.00	7,649	AM10.92	3,752	96.7	CM9.92	3,897	97.2
CF10.92	0.00	74.0	4.2	"	" " "	6.10	7,095	AM1.92	3,158	98.8	CM10.92	3,937	98.7

Table 8: Females angled at the Juniper Barrier - October 6, 1992

								Angled Male			Control Male		
ID Number	**Time Played (min.sec)**	**Length (cm)**	**Weight (Kg.)**	**Age**	**Spawning Date**	**Egg Diameter (mm)**	**Total Number of Eggs**	**Male ID Number**	**Initial Number of Eggs**	**% Pre-hatch Egg Survival***	**Male ID Number**	**Number of Eggs**	**% Pre-hatch Egg Survival***
AF1.92	19.40	100.0	10.7	N\A	Oct. 19/92	6.40	16,146	AM2.92	8,961	98.8	CM1.92	7,175	99.1
AF2.92	27.30	98.0	9.9	"	" " "	6.50	12,635	AM3.92	6,635	93.3	CM2.92	6,000	95.1
AF3.92	6.30	79.0	4.8	"	" " "	6.25	6,925	AM4.92	3,628	97.7	CM3.92	3,297	98.5
AF4.92	10.30	74.0	4.7	"	" " "	6.55	6,457	AM5.92	3,068	98.7	CM4.92	3,389	96.4
AF5.92	10.03	88.0	6.4	"	" " "	6.30	9,583	AM6.92	3,063	99.0	CM5.92	6,520	98.3
AF6.92	12.15	81.0	4.	"	" " "	6.70	5,062	AM7.92	2,435	99.0	CM6.92	2,627	98.6
AF7.92	9.00	81.	8.8	"	" " "	6.80	10,880	AM8.92	5,211	97.5	CM7.92	5,669	98.6
AF8.92	9.00	77.0	4.8	"	" " "	6.50	6,333	AM9.92	3,323	96.1	CM8.92	3,013	98.2
AF9.92	11.00	74.0	4.1	"	" " "	6.50	6,016	AM10.92	2,946	98.9	CM9.92	3,077	98.6
AF10.92	4.00	70.0	3.6	"	" " "	6.50	5,279	AM1.92	2,651	99.2	CM10.92	2,628	99.2

Table 9: Pre-hatch, hatch, and feed-up survival for eggs and fry from angled and control salmon collected at the Juniper Barrier, October 11, 1991 and October 6, 1992.

	Pre-hatch egg survival (%) Mean (range)		Survival to Hatch (%)		Survival to Feed-up (%)	
Mating Cross	**1991**	**1992**	**1991**	**1992**	**1991**	**1992**
Angled Female x Angled Male	92.1 (72.6-98.7)	97.8 (96.1-99.2)	94.1	97.3	93.0	96.2
Angled Female x Control Male	93.2 (72.8-98.7)	98.1 (95.1-99.2)	94.8	97.7	93.8	96.8
Control Female x Angled Male	98.2 (96.6-99.7)	98.7 (96.7-99.6)	98.7	98.4	97.4	97.1
Control Female x Control Male	96.6 (88.2-99.2)	96.9 (90.2-99.5)	97.3	96.4	96.1	94.7