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International Council for the Exploration of the Sea

C.M. 1977/M:16
Anadromous and Catadromous
Fish Committee

EFFECTS OF REARING REGIME AT CRAIG BROOK NATIONAL FISH HATCHERY ON SUBSEQUENT RETURN OF ADULT ATLANTIC SALMON (*SALMO SALAR* L.) TO RIVERS IN MAINE, U.S.A.

by

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[1] Jointly supported by the U.S. Fish and Wildlife Service, University of Maine, and Maine Department of Inland Fisheries and Wildlife.

ABSTRACT

The purpose of this study was to determine if rearing regime could be analyzed by multiple regression statistics to identify possible reasons for success or failure of hatchery lots planted in different years in different rivers. Data for lots were collected from hatchery records and tabulated for automatic data processing. Standard regression procedure was used. Only five of 493 multiple regressions were significant at $p = 0.05$ confidence level. I tentatively concluded that past history at Craig Brook National Fish Hatchery had little effect on percent return of smolt releases.

INTRODUCTION

Atlantic salmon have been raised at Craig Brook National Fish Hatchery in East Orland, Maine, U.S.A., under different rearing regimes since 1963. These salmon were derived from five separate sources and stocked in four major rivers in eastern Maine: Penobscot, Narraguagus, Machias and Union. The purpose of this study was to determine if rearing regime could be analyzed by multiple regression statistics to identify possible reasons for success or failure of hatchery lots planted in different years in different rivers.

Despite large stockings, adult sea-run salmon return has been poor in New England. To date, no salmon have been taken in the Merrimack River system (Belak 1977) and only five have been captured in the Connecticut River system (Int. Atl. Salmon Found. 1977). Angling in Maine accounts for over 300 salmon per year with about 700 more tallied in the fishways, but returns are inconsistent. Over 50 percent variation in return occurs (Belak 1977). In Canada, in 1976, Prince Edward Island, New Brunswick and Quebec had increased commercial salmon catches, while Newfoundland and Nova Scotia had decreased commercial salmon catches (Int. Atl. Salmon Found. 1976). It was hoped that multiple regression analysis would pinpoint factors that would relate hatchery regime to adult return to the river. In New England, salmon runs consist mainly of hatchery fish. In Canada, runs consist mainly of wild fish. The St. John River in Canada has runs consisting of over 50 percent wild fish, even though a large hatchery exists below the Mactaquac dam (Penney 1977, unpublished, Resource Branch, Environment Canada, Halifax, Nova Scotia).

METHODS AND MATERIALS

Smolts stocked in Maine rivers in 1963, were raised from New Brunswick (Miramichi) strain eggs. Different "strains" have since been developed from progeny of Miramichi eggs: Penobscot, Narraguagus, Machias and Narraguagus-Machias. Allelic frequencies of 18 enzymes comprising 50 genetic loci were analyzed for five Maine rivers (Roberts 1976). Allelic frequencies for each respective protein were not significantly different, emphasizing common origin of Maine river stocks.

Data were collected for 1963 - 1973 for plantings in the Machias River, 1963 - 1971 for plantings in the Penobscot River and 1973 - 1974 for plantings in the Union River.

Data for 48 lots were collected from hatchery records, tabulated (Table 1) for automatic processing and analyzed according to 20 variables related to stocking data, 44 variables in rearing data and 26 variables in egg and fry data. From information of Table 1 additional data were calculated (Table 2). Variables tested were related to type of diet, biochemical composition of diet, temperatures, size of fish, density of fish per area and volume, water flow, time in transit to stocking site, mortality, food conversion, type of disease treatment and concentration of disease treatment. A lot was determined by parental stock and year. For example, progeny of Penobscot salmon in fall 1960, would be lot P61. Lots were stocked in rivers by trucking usually in April through June. Salmon returns to the river were obtained from Maine Atlantic Sea Run Salmon Commission as percentages of salmon released. Percentages form a binomal distribution rather than a normal distribution (Zar 1974) so all percentage data were transformed by:

$$x' = \arcsin(x)^{\frac{1}{2}}$$

X' represents transformed data and x is percentage divided by 100. Collected and calculated data were independent variables and percent return was the dependent variable Y. In eight cases, regressions were run for each river system. In three cases, when insufficient number of Y return occurred, data was combined from different rivers. Data were set up and run using Multiple Regression Analysis, Subprogram Regression, of Statistical Package for the Social Sciences. Standard regression procedure was used. F values were tested for significance at the 0.05 confidence level using a table of critical values of F distribution in Zar (1974).

RESULTS AND DISCUSSION

Of 493 multiple regressions, only five were significant. Three of the significant regressions occurred in 1973 - 1974 Union River releases.

For three months before release in May the variables related to water flow; gallons per minute, number of changes per hour, and number of fish per cubic foot per minute, tested significant (Table 3) for Union River releases. The null hypothesis for January, February and March was that the multiple correlation coefficient was zero.

For March data, I rejected the null hypothesis ($0.02<P(F \geq 85.39)<0.05$). The regression equation was $Y' = 22.822 + 0.085(x(1)) + 0.004(x(2)) - 4.196(x(3))$. For March, 99.22 percent of variation in Y was explained by x(1) to x(3). This is a high amount of variation in Y explained by x. For insignificant regressions, amount of variation in Y explained by x ranged from 0.00 percent to 99.78 percent. Six different lots were stocked during 1973 - 1974, so only a small number of cases were available. Denominator degrees of freedom were small for all tested regressions in Union River releases (df = 2). If more degrees of freedom were available, more regressions might have tested significant. Of three independent variables for March, only x(1) was significant at 0.05 confidence level (Table 4). In a standard regression method, each variable is treated as if it had been added to the regression equation in a separate step after all other variables had been included (Kim and Kohout 1975). Gallons of water flow per minute contributed more to the significance of the regression than did number of water changes per hour or number of fish per cubic foot of water per minute.

For February data, I rejected the null hypothesis ($0.02<P(F \geq 29.49)<0.05$). The regression equation was $Y' = 22.968 + 0.087(x(1)) + 0.000(x(2)) - 3.914(x(3))$. For February, 99.49 percent of variation in Y was explained by x(1) to x(3). Again only gallons of water flow per minute were significant at 0.05 confidence level (Table 4).

For January data, I rejected the null hypothesis ($0.02<P(F \geq 107.13)<0.05$). The regression equation was $Y' = 23.129 + 0.082(x(1)) + 0.004(x(2)) - 4.244(x(3))$.

For January, 99.38 percent of variation in Y was explained by x(1) to x(3). Only gallons of water flow per minute were significant at 0.05 confidence level (Table 4).

In January to March, approximately 450 gallons of water per minute flowed through 800 square feet of raceway. In April, approximately 540 gallons of water per minute flowed through 800 square feet of raceway and in July to December, approximately 585 gallons of water per minute flowed through 800 square feet of raceway.

The other two significant regressions occurred in 1969 - 1972 Penobscot River releases. Weight data; weight per square foot, weight per cubic foot, and weight per cubic foot per minute, and stocking data; miles in transit, percent river flow above mean, and number of salmon per pound, tested significant for Penobscot 1969 - 1972 releases (Table 5). The null hypothesis for both regressions was that the multiple correlation coefficient was zero.

For December data, I rejected the null hypothesis ($0.02<P(F\geq 8.34)<0.05$). The regression equation was $Y' = 74.409 + 0.066(x(1)) - 34.877(x(2)) + 28.587(x(3))$. For December weights, 83.34 percent of variation in Y was explained by x(1) to x(3). X(2) and x(3) were significant at the 0.05 confidence level (Table 6). Weight per square foot contributed negligibly to the significance of the regression compared to weight per cubic foot or weight per cubic foot per minute. This is a surprising result because Atlantic salmon growth is related to density in the hatchery (Fenderson and Carpenter 1971 and Keenleyside et al. 1962). If a significant statistic was expected it would be with weight per square foot rather than weight per cubic foot or weight per cubic foot per minute because Atlantic salmon do not "stack" in hatcheries as Pacific salmon do (personal communication, Alfred Meister, Atlantic Sea Run Salmon Commission).

Fpr stocking data, I rejected the null hypothesis ($0.02<P(F\geq 9.58)<0.05$). The regression equation was $Y' = 22.922 - 2.78(x(1)) + 0.815(x(2)) - 6.928(x(3))$. In stocking, 80.42 percent of variation in Y was explained by x(1) to x(3). Only x(2), percent water above mean for release date, was significant at 0.05 confidence level. Miles in transit to release site and number per pound contributed less to significance of the stocking regression than percent water above mean for release date.

All significant regressions occurred with data taken from stocking or from months just prior to stocking. Rearing regime earlier than six months prior to stocking was never related to percent return. This suggests that events near to stocking are more important than the earlier history in the hatchery. On the basis that only five of 493 regressions were significant, I tentatively conclude that past history at Craig Brook National Fish Hatchery had little effect on percent return of smolt releases. This conclusion was contrary to my expectation and I offer the following qualifications.

Some data points were missing and returns were not adjusted for sea captures. At times hatchery records were incomplete because in hot summer months high temperatures made handling fish impossible, hence measurements were not taken. Sea returns were unavailable for some lots and sea returns from marked lots varied by over 100 percent from each other. Atlantic salmon are territorial (Chapman 1966) and I expected increased density to lead to greater aggressive behavior, poorer quality fish and greater mortality. I also expected quality of diet and disease treatments to have played a part in ability of adults to return. A fish fed a poor quality diet would be less likely to survive or grow as well as a fish fed a higher quality of diet. A sickly fish or one susceptible to diseases would be less likely to return from the ocean.

ACKNOWLEDGMENTS

I thank Dr. Richard W. Hatch for help in the data bank format, Atlantic Salmon Investigations, U.S. Fish and Wildlife Service, for financial support provided by contract number 14-16-0008-2136, the Craig Brook National Fish Hatchery personnel for information about rearing regimes, the Atlantic Sea Run Salmon Commission for data on returns and Dr. James. D. McCleave for advice and criticisms.

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Table 1. Monthly lot data collected from Craig Brook National Fish Hatchery, East Orland, Maine (abbreviations in parentheses).

Stocking Data

lot number
year stocked
date stocked
river
smolt year
where stocked
rearing unit
mark applied
number stocked (no)
weight stocked (wt)
water conditions
miles transit (mi)
time transit (tt)
hatchery temp. (ht)
river temp. (rt)
temp. change (tc)
size range
stocking remarks
percent water rise (ph2o)

Egg/fry Data

strain
lot number
month
remarks
number per pound (nplb)
number
weight
weight gain
pounds liver
pounds Ewos
conversion (con)
percent mortality (pmort)
mortality
days since take (rd)
percent liver in diet
average temp.
percent protein in Ewos
percent carbohydrate in Ewos

Rearing Data

lot number
month
rearing unit
water source
rearing remarks
square feet (sf)
gallons per minute (gpm)
depth
number
weight
mortality (mort)
avg. temp. (at)
max. temp. (mxt)
min. temp. (mnt)
weight increase (wtincr)
total food
percent diet liver (pl)
percent diet Ewos (pe)
percent diet other (po)
formalin treatment times (form)
malachite green treatment times (mg)
other treatment times (oth)
concentration formalin (cform)
concentration malachite green (cmg)
concentration other (co)
percent protein in Ewos (pp)
percent fat in Ewos (pf)
percent carbohydrate in Ewos (pcho)

Egg/fry Data (cont.)

weight per cubic foot (wpcf)
percent gain weight (pgw)
food fed in percent body weight (fbd)
temp. units since take (tu)
total temp. units since take (ttu)
percent Ewos in diet
gallons per minute flow
percent fat in Ewos

Table 2. Monthly lot data calculated from collected data from Craig Brook National Fish Hatchery, East Orland, Maine (abbreviations in parentheses).

Stocking Data	Rearing Data
number per pound (nplb)	number per pound
	cubic feet (cf)
	cubic feet per minute (cfpm)
	water changes per hour (h2o)
	mortality per number (mpn)
	number per square foot (npsf)
	number per cubic foot (npcf)
	number per cubic foot per minute (npcfpm)
	weight per square foot (wpsf)
	weight per cubic foot (wcf)
	weight per cubic foot per minute (wpcfpm)
	temp. range (tr)
	food per salmon (fps)
	weight per salmon (wps)
	change in weight per salmon (cwps)
	conversion

Table 3. Significant regressions for Union River releases in 1973 - 1974 (n = 6, F_o^* = 39.20).

Regression	x(1)	x(2)	x(3)	Fc^+
March	gpm	h2o	npcfpm	85.39
February	gpm	h2o	npcfpm	129.49
January	gpm	h2o	npcfpm	107.13

$^*F_o$ is critical F value at o.05 confidence level; df = 2.

+Fc is calculated F value.

Table 4. Tests of independent variables for significance in Union River releases 1973 - 1974 ($F_o^* = 38.5$).

	March Fc^+	February Fc^+	January Fc^+
x(1)	72.51	110.68	91.32
x(2)	0.11	0.00	0.14
x(3)	19.64	24.77	25.43

$^*F_o$ is critical F value at o.05 confidence level; df = 2.

+Fc is calculated F value.

Table 5. Significant regressions for Penobscot River releases in 1969 - 1972 (n = 11).

Regression	x(1)	x(2)	x(3)	Fo^*	Fc^+
December weight	wpsf	wpcf	wpcfpm	7.76	8.34
Stocking	mi	ph2o	nplb	5.89	9.58

Table 6. Tests of independent variables for significance in Penobscot River releases in 1969 - 1972

	December weight (df = 5, $F_o^* = 10$)	Stocking (df = 7, $F_o^* = 8.07$)
	Fc^+	Fc^+
x(1)	0.005	0.935
x(2)	22.626	26.908
x(3)	14.14	1.851

+ Fc is calculated F value.

$^*F_0$ is critical F value at 0.05 confidence level.