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THE MARINE NET-PEN CULTURE OF CHERRY OR MASU SALMON,

ONCORHYNCHUS MASOU, AND TWO HYBRID CROSSES

IN PUGET SOUND, WASHINGTON

by

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INTRODUCTION

The cherry or masu^{1/} salmon, (Oncorhynchus masou), is the little known sixth Pacific salmon species. They are native only to the western North Pacific and are distributed along the coastal area of the Sea of Japan and the west coast of the Kamchatka Peninsula (Figure 1). They are most abundant in the Hokkaido region of Northern Japan (Tanaka 1965), but range farther south than other Pacific salmon species in Asia. According to Tanaka (1965), these fish are able to tolerate higher freshwater temperatures than other Pacific salmon species. They prefer temperatures of about 12°C but enter spawning streams when temperatures are as high as 23°C.

Masu salmon mature as three or four-year old fish, with three-year olds most prevalent (Tanaka *ibid*). They resemble the coho (O. kisutch) of the eastern North Pacific both morphologically and in their life history, but differ in that they have large round parr marks as presmolts with a distinct purplish-pink hue to the external surface as opposed to the brownish-yellow hue and narrow parr marks of coho. When smolting, the two species are similar in appearance; i.e., slender and silver with black fringed caudal and dorsal fins. Maturing masu salmon return to their home streams in the spring months as bright-silver, actively feeding fish and are reported to provide a river sports fishery similar to steelhead fisheries on the west coast of North America (Washington State Department of Fisheries, Internal Report 1971, Christie 1970).

Because of their preference for warmer waters and their similarity to coho salmon, masu salmon eggs were imported by the Washington State Fisheries Department in 1971 in order to study their potential for the enhancement of

^{1/} Masu salmon - A Japanese term commonly used to designate O. masou outside Japan.

declining fisheries in Puget Sound. The imported stock originated from the Shari River of Hokkaido Island.

In 1973, the National Marine Fisheries Service (NMFS), in cooperation with the Washington Department of Fisheries began a feasibility study to determine: 1) if masu salmon could be reared to maturity and successfully spawned from saltwater net-pens (successful brood stock rearing would provide alternative egg sources in the case of failure from wild releases) and 2) the applicability of masu-salmon and two of its hybrids to saltwater net-pen culture for production of pan-size market fish.

A previous study (Mighell and Dangel 1975) indicated that ova of two species of Pacific salmon crossed with male masu salmon had a high hatching rate. The two hybrids, chinook (O. tsawytscha x masu and pink (O. gorbuscha) x masu salmon had survival rates of 90% and 70%, respectively, through a size of approximately 3 g. Both hybrids produced subyearling and yearling smolts at a 60% and 100% rate, respectively. Crosses of male masu salmon and other Pacific salmon females as well as rainbow trout (Salmo gairdneri lewisi) had much lower survival rates.

Net-pen culture of Pacific salmon broodstocked and pan-size salmon for market has been successfully practiced in Puget Sound experimentally and on a production basis (Novotny 1975). Coho salmon rearing has been most successful due primarily to their relative resistance to diseases endemic to the Puget Sound Basin. At least one hybrid, a pink x chinook salmon cross has been shown to have potential for production rearing but is more susceptible to both fresh and saltwater diseases Novotny *ibid*).

MATERIALS AND METHODS

The freshwater rearing was conducted at the NMFS laboratory in Seattle, Wash. and saltwater rearing was at the NMFS Puget Sound research station near Manchester, Wash. The fish were grown in saltwater in knotless nylon net-pens measuring 12.0 x 21.0 m in area and 1.8 m in depth with mesh openings of 7.5 mm, stretched. The fish densities at the start and end of the study were 0.1 lb/ft³ and 1 lb/ft³, respectively. The ending density was 0.5 lb/ft³, respectively. The ending density was 0.5 lb/ft³ in the pen used to raise broodstock masu salmon. All fish were fed an Oregon Moist Pellet (OMP) diet, ad libidum, 7 days per week.

Broodstock masu salmon were examined for signs of maturity weekly from the onset of secondary sexual characteristics in late July 1974 throughout the spawning period in late September. Spawning was by the standard dry method of Leitritz (1959). Mature fish, from saltwater pens, were anesthetized with a 1/20000 solution of MS-222^{2/} and rinsed in cool (8-11°C) fresh water immediately prior to spawning. Male to female fertilization ratio was 2:1 and eggs were incubated in Heath^{3/} incubators.

To determine the applicability of masu salmon and the two hybrids chinook x masu salmon and pink x masu salmon for production of pan-size market fish, the fish were reared over a time period (early summer to following spring) typically used by commercial growers. The fish type and the period of rearing is shown in Table 1.

^{2/} Tricaine Methanesulfonate

^{3/} Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

TABLE 1.--Brood year, smolt age and size and period of rearing in salt water of coho, masu and hybrid salmon stocks used for net-pen group comparison.

Stock	Brood year	Smolt age (mo.)	\bar{X} wt(g)	Entry into seawater pens	Seawater rearing time/days
Masu	1972	18	16.4	6-06-74	344
Chinook x masu	1972	17	19.0	5-16-74	365
Pink x masu	1972	7	5.8	8-03-73	193
Masu	1974	18	35.1	6-24-76	320
Chinook x masu	1975	5	5.3	6-24-76	320
Coho	1974	18	22.3	6-24-76	320

Specific growth rates (% increase in body wt/day) were determined by the methods described by Brett et al. (1969).

RESULTS AND DISCUSSION

REARING OF MASU SALMON BROODSTOCK

Masu salmon smolts (X - wt = 60.0 g) grew to an average wt of 312.3 g at maturity after 14 months of rearing in saltwater net-pens. Mature females were larger (\bar{X} wt = 380.7 g) than mature males (22.4 g). Survival in salt water was 92%.

The development of secondary sexual characteristics, such as the loss of silvery appearance, reappearance of parr-marks and hooking of the jaw began late in the 11th month of saltwater rearing (July) and progressed through the spawning periods from 16-25 September 1974. Eight-four (84) percent of the fish had spawned at an age of 3 years and the remainder presumably would have spawned at 4 years but were subsequently lost to animal predation.

Biweekly mean temperatures during the rearing and maturation period are shown in Figure 2. Maturation began with temperatures averaging as high as 14.0°C, but the temperature at spawning was 12.5°C. The late September spawning

coincided with reports of spawning wild masu (from the same egg source) in Minter Creek, Washington.^{4/}

Wild masu females from the Hokkaido area of Japan averaged about 2.5 kg and produced about 2,500 eggs/female (Christie 1970). Our net-pens females averaged 0.3 kg and 337 eggs. A size-fecundity correlation (Figure 3) showed a positive correlation (0.657) at the 95% confidence level with some variability due to in part to variation of egg diameter. The eggs of the net-pen reared masu were large (\bar{X} diam = 6.46 mm) compared with wild fish (5.0 mm) as reported by Christie (1970). Egg survival ranged from 23.4% per female to 99.1% and averaged 84.6%.

Vibriosis, a common saltwater disease caused by the bacterial agent, Vibrio anguillarum, was not a factor in the rearing of masu salmon in net-pens. There were no mortalities attributed to vibrio during the 14-months growing period despite the fact that coho salmon being reared in adjacent pens were sustaining steady losses due to vibrio. Myxobacterial epizootics did cause occasional losses during the periods of rapid temperature change, but were controlled effectively by administration of dietary oxytetracycline (Terramycin) (Wood 1974).

PAN SIZE REARING OF MASU SALMON AND TWO HYBRIDS

Pan size (170-380 g) coho salmon are produced for market in net-pens in Puget Sound in a growing period of from 200-370 days (Novotny 1975). On that basis, the masu salmon and the chinook x masu hybrid salmon qualified for pan size production in this study, but the pink x masu salmon hybrid could not be

^{4/} Gallagher 1975 - personal communication.

evaluated due to excessive losses to bacterial kidney disease (BKD) during the experimental rearing period.

Because of the widely varied saltwater entry dates (Figures 4 and 5) growth rates were plotted against cumulative temperature units (1 T.U. = 1°C/24 hr). The growth of 1974 broods of coho and masu salmon and 1975 brood chinook x masu hybrid salmon is shown in Figure 4, while Figure 5 shows the growth of the 1972 broods of masu salmon, chinook x masu hybrid salmon and pink x masu hybrid salmon, as well as 1974 coho salmon for comparison purposes. In Figure 4, using coho salmon growth (0.42%/day) as a standard, the masu salmon growth was substantially lower (0.26%/day) during the first 1,250 thermal units (Ca. 100 days reared in salt water). During the same period, the chinook x masu hybrid salmon, which entered salt water as a subyearling smolt of only 5.3 g mean weight, grew at a rate of 0.94% per day. Each of these groups grew at similar rates between 0.20 and 0.30%/day after the first 100 days through the 320th day (3,200 T.U.). By the ending date, the chinook x masu hybrid salmon had actually equaled the size of coho salmon.

Growth of the 1972 broods of masu, chinook x masu, and pink x masu salmon, along with the 1974 coho salmon, are plotted in Figure 5. Growth of the 1972 brood chinook x masu salmon is similar to that of the 1974 coho salmon. The exceptional growth rate (1.29%/day) of the small (\bar{X} wt = 5.79 g) 1972 pink x masu hybrid salmon through 1,250 T.U. allowed them to equal the size of the 1972 chinook x masu salmon in that period, and reach a size after 193 days of saltwater rearing that was 80% of the weight of the coho salmon.

All groups, regardless of entry date and species, reached a size of 200-220 g means weight in 320 days of saltwater rearing with two exceptions. The pink x masu salmon growth experiment was terminated after 193 days due to

the loss from BKD and the 1972 chinook x masu salmon, affected by myxobacterial disease, about 120 days after saltwater entry, grew to just 196 g mean weight.

A summary of beginning and ending size data, condition index, and ending survival is compiled in Table 2. The high condition index of the chinook x masu salmon was visually evident during sampling procedures. The deep body configuration and integrity of the scales is shown in Figure 6. Pink x masu hybrid salmon also had a relatively deep body and only minor scale loss.

Biweekly mean temperatures during the saltwater rearing period of each of the species-brood groups is shown in Figure 7. The low temperature of near 7°C occurred in early March, while the high temperature of 13-14°C occurs in July or early August.

Survival of the 1974 brood coho salmon, 1975 brood chinook x masu hybrid salmon and the 1974 brood masu salmon, all reared in salt water from 24 June 1976 to 10 May 1977 was 80%, 60%, 53% of starting smolts, respectively (Figure 8). Coho salmon (control) mortalities were gradual at about 1.9% per month, while chinook x masu salmon mortality was heavy in the first 75 days, when approximately 37% of the population died from infestation with the freshwater protozoan parasite, Ichthyophthirius multifiliis. Masu salmon losses were gradual but at a rate of about 4.5% per month over the 10-month period.

The 1972 brood masu and chinook x masu salmon survival rates at approximately 300 days after saltwater entry were 75% and 94%, respectively. The higher survival of these fish was probably due to a low incidence of myxobacterial disease during the spring and fall of 1974.

The pink x masu hybrid salmon (1972 brood) had an initial mortality of 40% during the first 40-days reared in salt water. This mortality was due to the inability of the smaller fish to adapt to salt water (osmoregulate). The mean

weight of the mortalities and survivors during the first 40 days in salt water was 2.16 g (n = 150, Sx = 1.99) and 5.18 g (n = 100, Sx = 2.70), respectively. Mortality diminished after 40 days but increased sharply beginning with the 130th day as a result of BKD.

SUMMARY

Masu salmon were successfully reared in saltwater net-pens under intensive culture conditions to provide broodstock for production of eggs and also for the production of pan-sized salmon for market. A hybrid cross between chinook salmon and masu salmon was also reared successfully to pan-size. Each of the stocks was reared during a growing season that corresponded to the summer-fall-winter schedule presently used by commercial growers.

The growth of masu salmon and the chinook x masu hybrid was similar to that of coho salmon. The body configuration of the chinook x masu hybrid was very similar to that of pure chinook salmon, being dorso-ventrally deep bodied. On the other hand, the masu salmon and the pink x masu hybrid resembled the more slender appearance of coho salmon. Scale retention of the two hybrids especially the chinook x masu, was superior to that of coho salmon particularly the chinook x masu hybrid.

The two hybrids also produced subyearling smolts in freshwater, unlike coho salmon which produce only yearling smolts when grown at ambient Puget Sound basin temperatures.

The survival rates of the masu salmon and chinook x masu hybrid were similar to that of the coho salmon in the experiment, while the pink x masu salmon survival was much lower due to BKD.

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