# Pen Rearing and Imprinting of Fall Chinook Salmon

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By

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## ABSTRACT

Pen rearing studies during 1986 completed the second of three years intended for rearing and releasing upriver bright fall chinook salmon (Oncorhynchus tshawytscha) from two study sites, a backwater and a pond, adjacetn to tne Columbia River; both areas are located in the Jonn Day Keservoir. Results of this study in 1984 and 1985 showed that fish could be successfully reared in net pens and that growth and physioloyical development of the off-station reared fish proceeded at a faster rate than in fish reared at a hatchery.

Transfer of fish from the hatchery to off-station sites at Social Security Pond (pond) and Rock Creek (backwater) during early March increased the period of rearing in 1986 by about four weeks. The increased period of rearing allowed all treatments of fed fish to reach a minimum weight of YU fish/lb by release. Differences in growth of fed fish between regular density treatments and additional, high density treatments (double and triple the regular densities) were not significantly different ($P > 0.05$), but growth of all fed fish reared off-station was again significantly better than that of hatchery reared fish ($P < 0.05$), Mortalities in all groups of fed fish were low.

Physioloyical development of fed fish was similar in all treatments. At release, development of fish at Social Security Pond appeared to be somewhat ahead of fish at Rock Creek on the same dates however, none of the groups of fed fish achieved a high state of smoltification by release.

Unfed fish grew poorly over the redring period, and at release were significantly smaller than either fed groups at the off-station sites, or the control groups reared at the hatchery ($P < 0.05$). Development of unfed fish toward smoltification was much slower than of fed fish. Mortality of all groups of unfed fish, including the barrier net, was relatively low.

Health of all fish reared off-station remained good over the rearing period, and no outbreaks of disease were noted. On-site marking and transfer of fish from the hatchery did not appear to have an adverse effect.

Estimated costs of rearing fed fish at regular, double, and triple the regular density were lower than for rearing a similar poundage of fish in a hatchery. However, estimated costs using present rearing scenarios in net pens at low densities and in a barrier net were high in relation to all other methods considered.

# INTRODUCTI0N

The pen rearing study completed in 1986 by the U.S. Fish and Wildlife Service was the second of three years designated for the rearing and imprinting of juvenile fall chinook salmon (Oncorhynchus tshawytscha) in netted enclosures in a backwater and in a pond along the John Day Reservoir. The overall objectives of the study are to:

1) Determine densities and feeding rations for rearing fish in enclosures in backwaters and ponds, and to compare off-station rearing success with that in a hatchery;
2) Rear and release fisn and determine the contribution of returning adults to the Columbia River fishery;
3) Evaluate cost-benefit of backwater and acclimation-pond rearing and develop a management plan for low-capital salmon production.

iiearing sites were selected in 1983 according to basic study requirements necessary for successful rearing, return, and capture of adults -- size and depth, accessibility, good water quality and natural food base, unique water source, and nearness to ndtural spawning habitat (Novotny et al. 1984). In 1984, rearing trials were conpleted at the two selected sites, Rock Creek, a backwater (river km 367) and Social Security Pond, a man-made pond adjacent to the Columbia River (river km 466). Densities, feeding rations, and general strateyies were developed during 1984 and used in the rearing and release of fisn in subsequent years. Over the cours of tne study, growth, survival , anti physioogical development have 32en monitored in all groups of fish reared at the off-station sites, and have been compared with control groups reared at Spring Creek National Fish Hatchery.

Study design and implementation in 1986 were essentially the same as in 198s with the incorporation of several improvements and additions: 1) physiological testing was expanded to include blood plasma thyroxine and cortisol analysis; 2) predator populations in the barrier net were reduced prior to stocking in order to reduce the high mortality experienced in previous years; 3) additional treatments of fed fish using higher densities in pens were tested at Rock Creek; 4) fish were transferred from the hatchery at an earlier date to extend the rearing period and to ensure that fed fish would reach the desired size of at least 100 fish/lb at release; 5) because of the early transfer date, it was necessary to implant coded wire tags in fish on site rather than prior to transfer from the hatchery; and 6) numbers of fish and densities were the same, but coded wire tagged groups were divided into four groups of 50,OOO fish/group, rather than 2 groups of 100,000 fish/group, for each of the treatments designated in the original study design to more accurately interpret and evaluate adult recaptures.

# METHODS

## Water Quality

Water temperatures were recorded daily one meter below the surface at both sites while temperature and oxygen profiles of the entire water column were recorded weekly throughout the rearing period. Pre-dawn oxygen readings were also recorded weekly to monitor possible oxygen decreases during the "non-photosynthesizing" hours. Other selected water quality parameters monitored at the beginning, mid-point, and completion of the rearing periods at the respective sites included: alkalinity to estimate buffering capacity; nitrate/nitrite nitrogen, orthophosphate, and total organic carbon as a measure of nutrient concentration; and total iron, total manganese, and un-ionized ammonia to monitor products of anaerobic activity. Water quality samples were transferred to a consulting chemical laboratory for analysis.

Other parameters recorded during the rearing period included Secchi disk, pH, and conductivity readings.

## Zooplankton

Zooplankton samples were collected every other week using methods employed in 1985 (Novotny et al. l986). Samples were collected at both sites in the open water, and additionally from within the barrier net at Rock Creek.

## Fish Rearing

Eggs for the pen rearing study were taken by the Oregon Department of Fish and Wildlife and reared by the U.S. Fish and Wildlife Service at Spring Creek (SCNFH) and Little White Salmon National Fish hatcheries (LWSNFH). Fish used for off-station studies were taken from SCNFH, while hatcnery-release controls were reared and released at LWSNFH; no upriver bright chinook salmon were released at SCNFH. Four groups of about 50,000 each were coded wire tagged at LWSNFH for return comparison with fish reared off-station (Appendix 1).

Fish were transferred from SCHFH to the Social Security Pond (SSP) and Rock Creek (RC) rearing sites between March 7 to 17 at 550 - 650 fish/lb (0.70 - 0.83 g). All fish were held in net pens prior to marking and distribution among the various rearing scenarios and were fed a full hatchery ration of Abernathy Dry feed at a rate of 3-4% body weignt/day.

Coded wire tagging was accomplished on-site at RC from March 10 to 25 (Appendix 2). All fish at RC were held in small mesh pens after tagging to assess tagging mortalities, and were subsequently distributed among the barrier net and various treatments of fed fish on April 3, 4, and 7 and among remaining treatments of unfed fish on April 12. Tagging at SSP (Appendix 3) took place from March 31 to April 5 and fish were distributed among the pens as they were tagged.

Four groups, each consisting of about 55,000 fish, were stocked at a size of 2.0 g in twelve 6.1 X 6.1 X 2.1 m net pens (79 $m^3$ rearing area) and reared at a "regular" density of 472 $g/m^3$ (0.029 $lb/ft^3$) at

SSP and 456 $g/m^3$ (0.028) $lb/ft^3$ at RC. The regular density treatment resulted in the stocking of about 18,500 fish/pen; only regular density treatments were reared at SSP. At RC additional treatments of fed fish of double and triple the regular density (860 $g/m^3$ and 1290 $g/m^3$, respectively), with two coded wire tagged groups of each, were reared in net pens. These densities required about 38,000 fish/pen at double density and 55,000 fish/pen at triple density; mean size of fish at stocking for these treatments was 1.6 g. All groups were fed a ration of 3-4% body weight/day over the rearing period. Regular density treatment fish were released at SSP on May 6 and at KC on May 15; fish reared at higher densities were released on May 20.

Groups of unfed fish were stocked in net pens on April 12 at mean densities of: low -- 28 $g/m^3$, medium -- 48 $g/m^3$, and high -- 108 $g/m^3$; two pens were included for each treatment. Study design called for 1000, 2000, and 4000 fish/pen in each of the respective treatments. However, actual numbers and densities stocked were somewhat lower -- about 960 fish/pen -- low density, 1650 fish/pen -- medium density, and 3700 fish/pen -- high density; average weight at stocking was 2.3 g/fish. Unfed fish in pens were released into the barrier net on May 29 as part of the marked group, for subsequent mark-recapture estimates.

Fish were stocked at about 16 g/m3 in four separate groups of 55,000 fish in the barrier net (0.6 ha; 17,842 $m^3$) on April 5 and 7. Prior to releasing fish into the barrier net, potential fish predators were removed using electroshocking, gill netting, seining, and hoop netting. Mean size of fish stocked into the barrier net was 1.6 g (about 275 fish/lb). A Petersen mark-recapture population estimate was

Completed on the day of release (June 4) to determine the number remaining in the enclosure. A group of 38,140 marked fish (non-adipose fin clipped) (see Appendix 9) was released into the barrier net six days prior to making the population estimate.

Growth differences among the various groups of fish were compared using a general linear models procedure for unbalanced samples (Zar l984). differences which proved to be significantly different ($P < 0.05$) were then compared using a Newman-Keuls multiple range test.

A chronology of significant events, including rearing and release dates, plus associated information may be found in Appendix 4. descriptions of rearing locations and chronologies of events in previous studies can be referred to in other annual reports -- Novotny et al. l984, Novotny et al. l985, and Novotny et al. 1986

## Fish Physiology and Health

Blood plasma thyroxine ($T_4$) and gill Na+-K+ ATPase levels were monitored as a smoltification indicator every other week for all groups of fed fish and for fish reared in the barrier net. These parameters were also sampled in fish at SCNFH and LWSNFH. Blood plasma cortisol was monitored as an indicator of stress prior to transfer to RC, at transfer, one day after, and one week after coded wire tagging. Additional cortisol samples were taken from control groups of fish at SCNFH, from all fed groups at RC, and from fish at SSP on April 23 as a means of comparing cortisol levels of the various treatments and locations. Thyroxine and cortisol analyses were completed by the

Oregon Cooperative Fishery Research Unit according to methods developed by Folmar and Dickoff (1981) and Schreck (1982), respectively. ATPase analysis was completed by the National Marine Fisheries Service Aquaculture Field Station, Cook, Washington using methods of Zaugg (1982).

Three 24-h seawater challenge trials were completed in 30% seawater (SW) using fish from hatchery control groups and from the regular density treatments at both sites as another measure of smoltification. Trials were run at the beginning (at transfer from the hatchery), at the mid-point, and near the completion of the rearing period. Data from trial one (time of transfer of fish to off-station sites) were omitted from the analyses due to high mortalities of SW-exposed fish and the need for extensive pooling of samples due to the small size of the fish ($\bar{x}$ wt=0.51 g, $\bar{x}$ fl=37.5 mm).

Fish used in the SW trials were anesthetized with MS-222 (10 mg/l) and transferred in aereated buckets to wet-lab facilities at the Willard Field Station and acclimated for 24 hours before treatment. Blood plasma samples were collected from fish after completing the 24-h period and sodium levels were subsequently analyzed using a flame photometer and methods developed by the manufacturer (Corning 1983).

Routine health assessment of fish reared in the hatchery and of each of the off-station treatments was completed on 20 fish every other week using methodologies developed by the Utah Division of Wildlife Resources (Goede, In Press). The method employs a combination of routine, ordered observations of internal organs, external characteristics, and simplified blood work-ups, including hematocrits, leucocrits, and blood serum protein concentrations.

Samples of fish were taken few a disease check two-three weeks after being distributed into the various treatments and at the conclusion of the rearing period. A1l groups were also monitored at the hatchery prior to transfer to the rearing sites. Disease profiles were completed by the Lower Columbia River Fish Health Center, Cook, Washington.

## Rearing Costs

Cost comparisons using treatments tested thus far in pen rearing studies (excluding unfed fish in pens) were compared with hatchery expenses using calculated efficiency ratios (Senn et al. l984). These comarisons must be considered preliminary until all three years of rearing are completed and expenses are modified as necessary with additional data. Expenses included in the comparison were cost of equipment, feed, labor, and operation and maintenance. Calculated efficiency ratios applied Present Value Theory (Senn et al. l984), which allows comparisons of all rearing methods using, a common denominator, incorporating the various life expectancies and expected replacement costs of each of the facilities.

## Adult Recovery

Two weirs were installed at SSP for adult recovery, one in the release channel, and one in an adjoining channel 0.4 km upstream. At RC a Merwin trap net (1.6 CM oar mesh, 9 m X 46 m lead, and 9 m X 9 m wings), gill nets (6.4 cm bar mesh) and a weir at the entry of RC proper were all used in adult recovery attempts. Numbers of adult returns were not available when this report was submitted.

## RESULTS

### Water Quality

Trends in temperatures at SSP and RC were similar to those recorded in 1985. Temperatures throughout most of March remained near, or below 10.0° C, warming rapidly by mid-April, and briefly spiking above 15.6° C (Fig. 1). Temperatures remained around 12.5° C from mid-April through mid-May, after which they increased steadily at both sites, reaching near 25.0° C at SSP and 20.0° C at RC by June 1.

Surface water temperatures were normally higher than subsurface temperatures (Tables 1,2). The thermal gradient from surface to near bottom (6 m) was moderate at both locations until late May - early June when the influence of surface warming caused thermal stratification at both sites. Dissolved oxygen was apparently sufficient during all rearing periods, but at SSP as temperature differences between thermal strata increased around June 1 dissolved oxygen decreased to low levels near bottom.

Measured values of other water quality parameters were similar to observed values recorded during 1985 (Table 3). There was no indication that fish reared at either of the off-station locations was adversely affected by ambient water quality. Flow at both sites

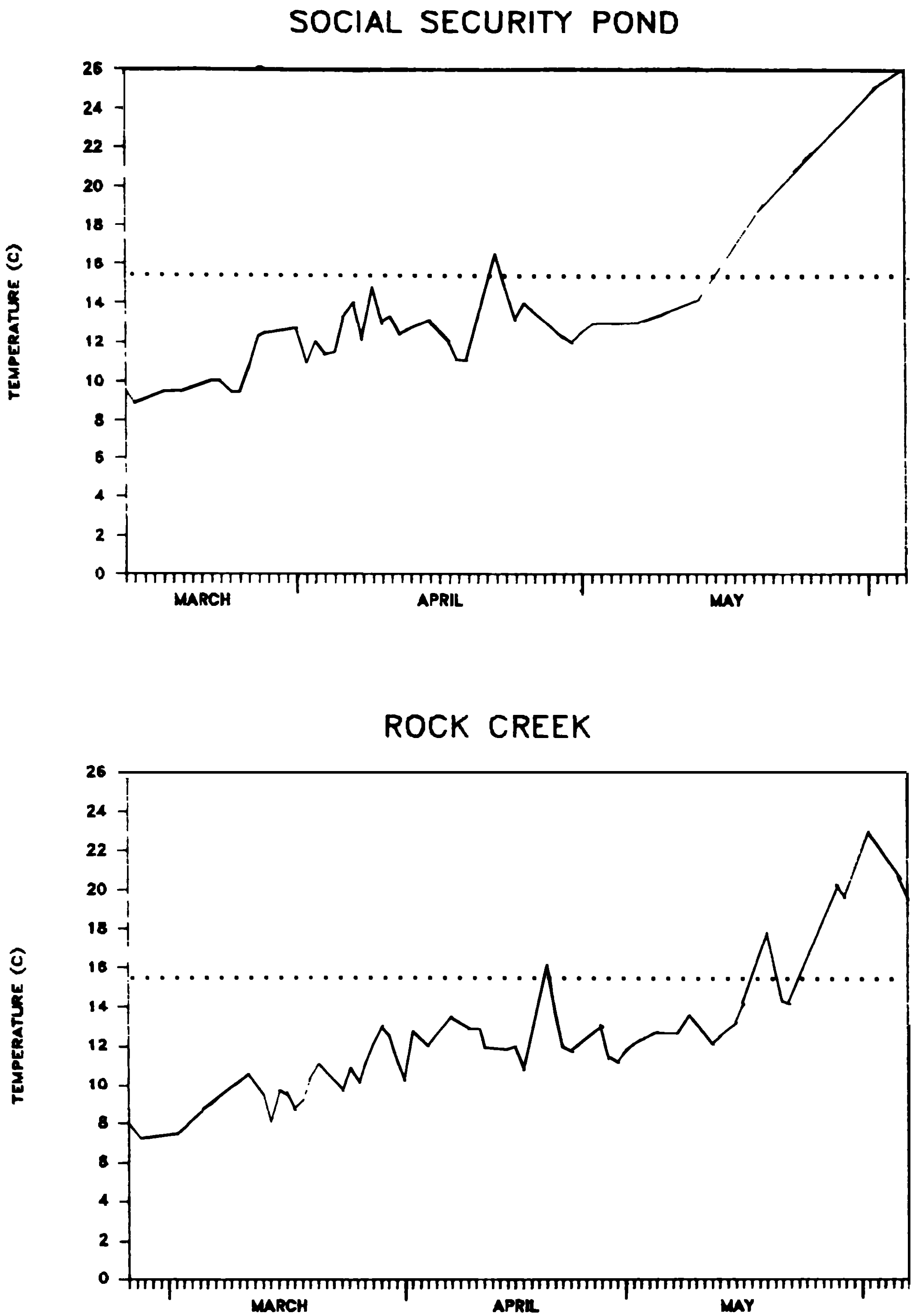



Figure 1. Water trempuratures at Social Security Pond and Rock Creek during rearing period, 1986.

Table 1. Weekly water temperature and dissolved oxygen profiles at Social Security Pond, 1986.

| DEPTH (m) | 3/4 | 3/13 | 3/18 | 3/25 | 4/1 | 4/8 | 4/16 | 4/22 | 4/29 | 5/6 | 5/12 | 5/19 | 5/30 | 6/3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Temperature C | | | | | | | |
| Surface | 8.7 | 9.5 | 9.5 | 9.5 | 11.0 | 14.8 | 12.0 | 15.0 | 12.0 | 13.0 | 14.1 | 19.0 | 25.0 | 26.0 |
| 2 | 7.1 | 9.5 | 9.2 | 9.5 | 10.6 | 12.1 | 11.1 | 14.9 | 12.0 | 12.5 | 13.9 | 15.9 | 10.6 | 19.8 |
| 4 | 7.0 | 8.9 | 9.0 | 9.3 | 10.4 | 10.4 | 11.0 | 11.5 | 12.0 | 12.1 | 13.0 | 13.2 | 13.0 | 18.0 |
| 6 | 6.1 | 7.0 | 8.0 | 9.1 | 10.1 | 10.2 | 10.5 | 11.0 | 12.0 | 12.0 | 12.9 | 13.0 | 13.0 | 13.5 |
| | | | | | | | Dissolved oxygen (mg/l) | | | | | | | |
| Surface | 13.0 | 11.8 | 11.8 | 11.6 | 12.4 | 12.8 | 12.6 | 12.4 | 11.6 | 13.4 | 11.8 | 12.4 | 13.2 | 10.2 |
| 2 | 12.8 | 11.4 | 11.8 | 11.6 | 12.0 | 12.5 | 12.2 | 12.8 | 11.6 | 13.4 | 12.0 | 13.6 | 13.4 | 10.2 |
| 4 | 12.9 | 11.2 | 11.5 | 11.4 | 12.2 | 10.3 | 12.1 | 11.2 | 11.6 | 13.6 | 11.6 | 10.9 | 11.0 | 8.2 |
| 6 | 12.6 | 10.8 | 9.4 | 10.8 | 10.4 | 8.8 | 10.0 | 8.7 | 11.4 | 12.6 | 11.4 | 7.7 | 2.4 | 2.0 |

Table 2. Weekly water temperature and dissolved oxygen profiles at Rock Creek, 1986.

| DEPTH (m) | 2/26 | 3/4 | 3/11 | 3/18 | 3/25 | 4/1 | 4/9 | 4/16 | 4/22 | 4/29 | 5/5 | 5/13 | 5/21 | 5/27 | 6/4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Temperature (C) | | | | | | | | |
| Surface | 7.9 | 7.8 | 10.2 | 8.7 | 10.8 | 10.2 | 13.0 | 11.9 | 13.8 | 11.4 | 12.8 | 12.5 | 14.5 | 20.2 | 19.5 |
| 2 | 7.8 | 7.0 | 9.0 | 8.5 | 9.2 | 10.0 | 13.0 | 10.5 | 13.0 | 10.9 | 13.0 | 12.0 | 14.5 | 18.0 | 16.7 |
| 4 | 7.0 | 6.4 | 8.3 | 8.0 | 8.8 | 9.9 | 11.9 | 10.0 | 11.9 | 10.5 | 11.6 | 11.7 | 12.5 | 13.0 | 14.7 |
| 6 | 6.8 | 6.2 | 8.0 | 8.0 | 8.1 | 9.0 | 9.6 | 9.9 | 10.5 | 10.5 | 11.1 | 11.2 | 12.5 | 12.6 | 13.9 |
| | | | | | | | Dissolved Oxygen (mg/l) | | | | | | | | |
| Surface | 9.7 | 10.5 | 10.8 | 11.0 | 11.8 | 10.7 | 12.8 | 12.4 | 9.8 | 8.7 | 10.2 | 10.3 | 10.4 | 10.1 | 9.8 |
| 2 | 9.8 | 10.6 | 10.6 | 11.0 | 11.4 | 10.4 | 12.6 | 10.2 | 10.2 | 8.6 | 10.3 | 10.3 | 10.6 | 10.5 | 12.1 |
| 4 | 10.3 | 10.8 | 10.6 | 11.1 | 11.2 | 10.2 | 10.4 | 8.6 | 10.4 | 7.8 | 9.6 | 10.0 | 10.1 | 10.1 | 11.8 |
| 6 | 10.3 | 10.8 | 10.7 | 11.0 | 11.0 | 9.4 | 6.3 | 7.4 | 8.7 | 7.9 | 7.8 | 9.2 | 9.6 | 9.5 | 11.1 |

Table 3. Selected water quality parameters monitored at Social Security Pond and Rock Creek during pen rearing studies, 1986 (all values expressed as mg/l).

| | Social Security Pond | | | Rock Creek | | |
|---|---|---|---|---|---|---|
| Parameter | April 7 | May 21 | June 2 | April 7 | May 21 | June 2 |
| Buffering capacity | | | | | | |
| Alkalinity as $CaCO_3$ | 98.0 | 66.0 | 65.0 | 44.0 | 71.0 | 79.0 |
| Nutrient concentration | | | | | | |
| Nitrate/nitrite - N | .83 | .10 | .03 | .57 | .14 | .14 |
| Orthophosphate - P | .069 | .031 | .029 | .053 | .015 | .020 |
| Organic Carbon (total) | 3.1 | 4.3 | 4.4 | 3.2 | 4.6 | 3.5 |
| Products of anaerobic activity | | | | | | |
| Iron (total) | .63 | .18 | .38 | .40 | .42 | .35 |
| Manganese (total) | .022 | .020 | .014 | .022 | .085 | .057 |
| Ammonia or N (un-ionized) | <.02 | <.02 | <.02 | <.02 | <.02 | <0.02 |

has been sufficient to retard the build-up of waste products or nutrients generated by unused food.

## Looplankton

Similar trends in the development of the zooplankton population at RC nave been observed over the last three years of the study--i.e. low densities in early spring followed by progressively higher densities over the rearing period. Extremely low numbers of zooplankton are present in the early spring but as the season progresses, the zooplankton population gradually increases.

Figure 2 Shows weight of zooplankton collected in KC in l985 and 1986 over the period of rearing in relation to maintenance rations (about 1.5% body weight/day) of various-sized fish reared at a density of about 16 g/m3 (barrier net density). At this density of Juvenile fish, and with no supplemental nutrition, zooplankton populations are not of sufficient abundance to support even the smaller fish until mid to late May.

## Fish Rearing at Off Station Sites

### Fed Fish Reared in Pens at Regular Density

Numbers of fed fish stocked and released at regular density were very similar at the two sites, showing high rates of survival over the rearing period (Table 4). Growth of fed fish in regular

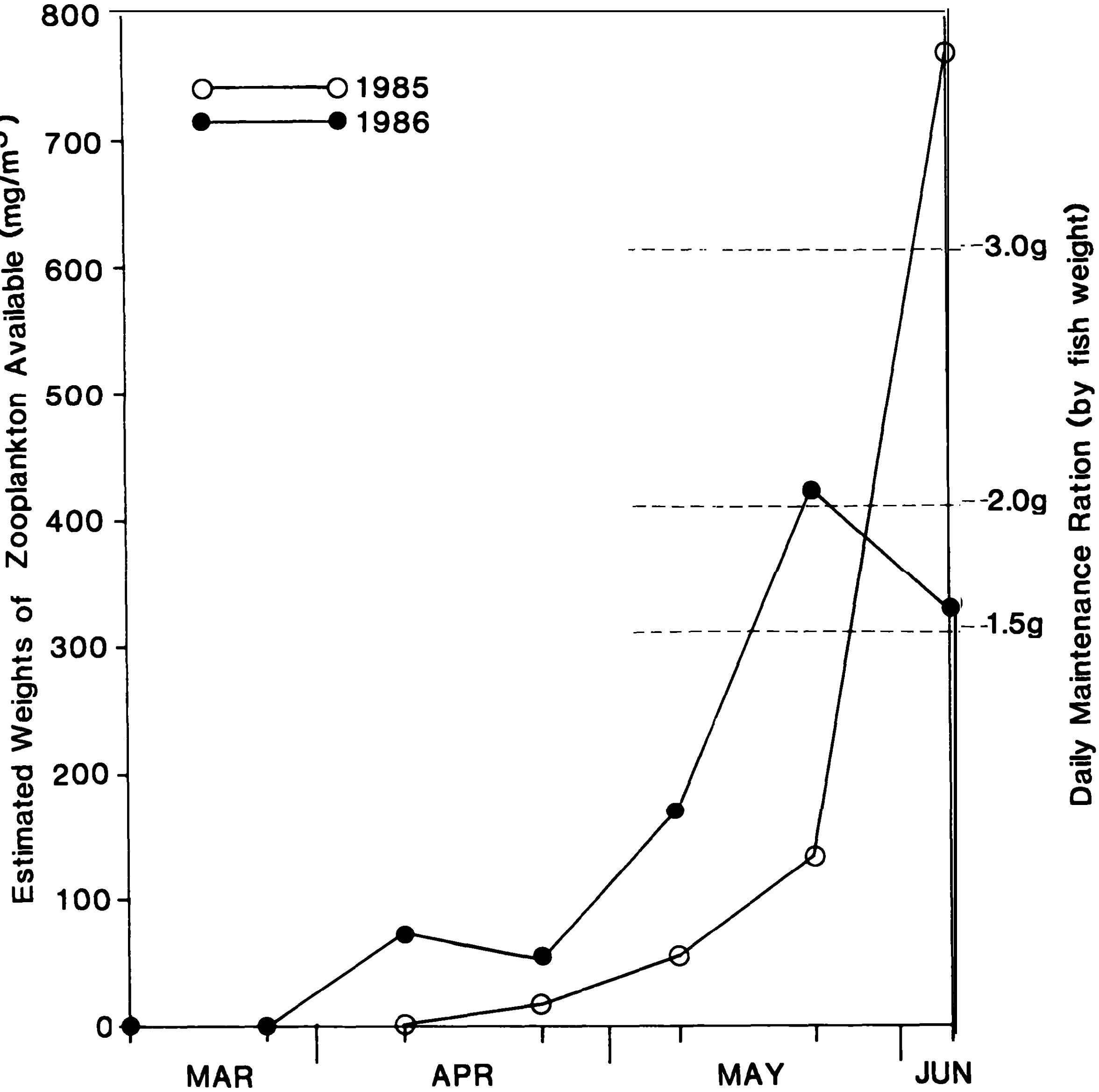



Figure 2. Zooplankton abundance (by weight) in Rock Creek during rearing period, 1985 and 1986 in relation to maintenance levels, (dotted lines) of various sizes of juvenile salmonids stocked at the lowest density tested in rearing trials - 16g/m3 (0.001 lb/ft3).

Table 4. Summary of stocking and release data for fed fish/pen reared in regular density treatments at Social Security Pond (SSP) and Rock Creek (KC), and in double and triple density treatments at Rock Creek, 1986

| | Stocking | At Release | Difference |
|---|---|---|---|
| Treatment Summaries | | | |
| Regular Density - SSP | | | |
| Number | 18,636 | 18,404 | 232(123)[a] |
| Number/pound | 227 | 90 | |
| Mean weight (g) | 2.0 | 5.0 | 3.0 |
| Pounds/cubic foot (g/m³) | .029(472) | .073(1174) | .044(702) |
| Total weight in pounds (kg) | 81(37.3) | 204(92.7) | 123(55.4) |
| Rearing period (Days) | April 3-6 | May 6 | (30-33) |
| Regular Density - RC | | | |
| Number | 18,328 | 17,946 | 382(287)[a] |
| Number/pound | 227 | 78 | - |
| Mean weight (g) | 2.0 | 5.8 | 3.8 |
| Pounds/cubic foot (g/m³) | .028(456) | .081(1318) | .053(862) |
| Total weight in pounds (kg) | 81(36.7) | 229(1040) | 148(67.4) |
| Rearing period (days) | April 7-8 | May 15 | (37-38) |
| Double Density - RC | | | |
| Number | 38,005 | 37,738 | 268(59)[a] |
| Number/pound | 284 | 70 | |
| Mean weight (g) | 1.6 | 6.5 | 4.9 |
| Pounds/cubic foot (g/m³) | .056(777) | .193(3105) | .137(2328) |
| Total weight in pounds (kg) | 157(61.4) | 540(245.3) | 383(1839) |
| Rearing period (days) | April 3 | May 20 | (47) |
| Triple Density - RC | | | |
| Number | 55,183 | 54,830 | 353(142)[a] |
| Number/pound | 284 | 72 | |
| Mean weight (g) | 1.6 | 6.3 | 4.7 |
| Pounds/cubic foot (g/m³) | .084(1105) | .272(4462) | .188(3357) |
| Total weight in pounds (kg) | 235(87.3) | 762(352.5) | 527(265.2) |
| Rearing period (days) | April 3 | May 20 | (47) |

[a] Difference includes both natural mortality and samples collected for physiological testing. (Parentheses indicate mean number of each group lost to natural causes).

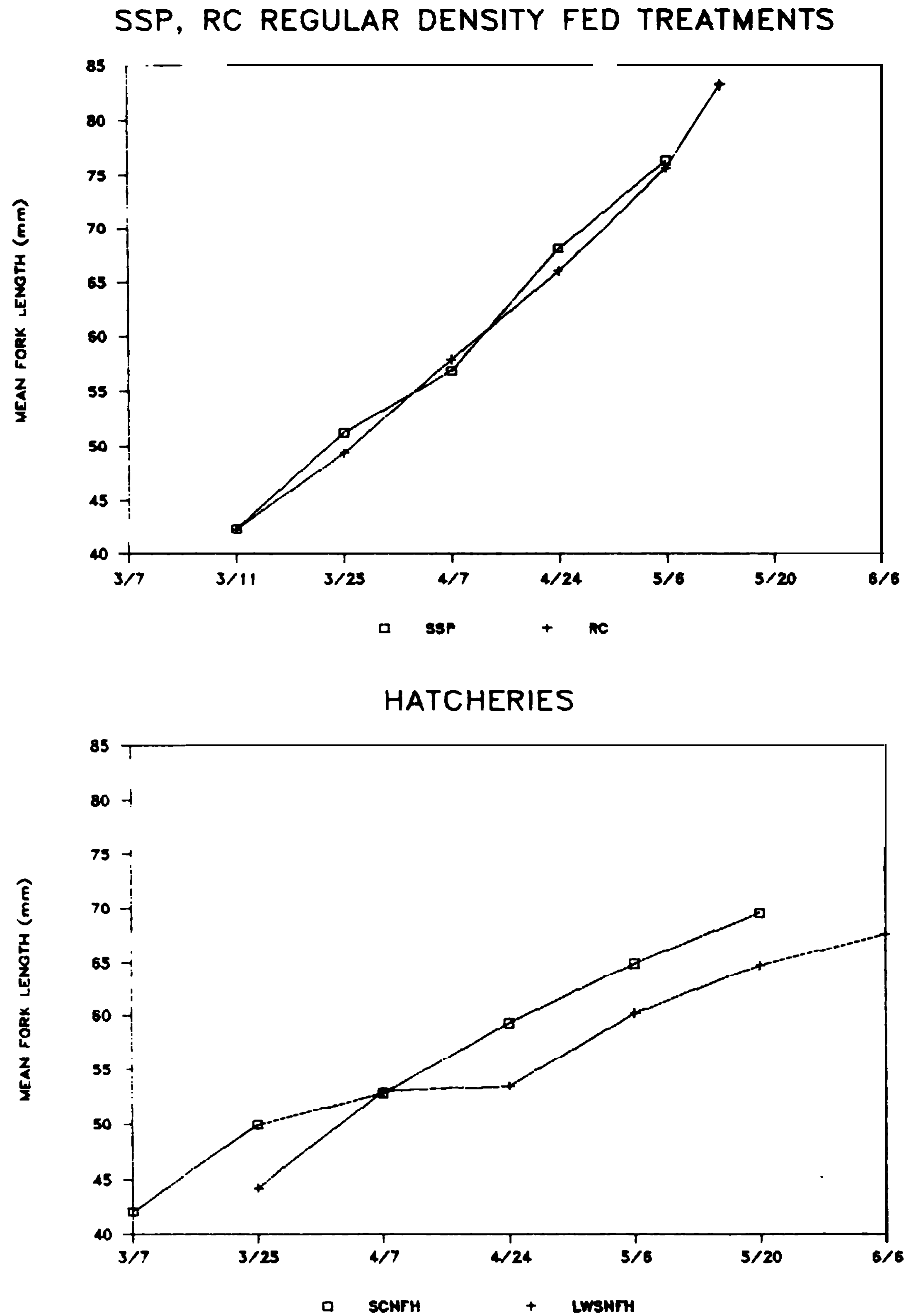



Figure 3. Growth (fork length) of fed fish reared at regular density at Social Security Pond and Rock Creek, and of fish reared at Spring Creek and Little White Salmon National Fish Hatcheries, 1986.

density treatments was also similar at SSP and KC (P > 0.05) over this period (Fig. 3; Appendix 5). At both locations sizes of fish at release were significantly larger (P < 0.05) than fish at the hatchery (Fig. 3; Table 5). The predetermined goal of rearing fish larger than 4.5 g ( < 100 fish/lb) was reached by the first week of May at both locatons. Due to increasing temperatures and the forecast of a continued warming trend, release of fish was begun at SSP May 6. Mean size of fish at release at SSP was 5.0 g (90 fish/lb). Fish were released from regular density treatments at RC the following week, on May 19, at a mean size of 3.8 g (78 fish/lb).

Survival of fed fish was high among the regular density pens at both sites during the 5-6 weeks of rearing--99.3% at SSP and 98.4% at RC (Table 4). Most of the mortalities occurred during the two-week period after redistribution (Appendix 6). This phenomenon was also observed during the two weeks after transfer to off-station sites in l985. During both years, handling and associated stress was regarded as the probable cause of the initially higher, but not excessive, mortalities. Disease was not manifested in fish in regular density treatments. However, all groups of fish taken from SCNFH were exposed to enteric redmouth disease (ERM) and it was detected among fish examined at release (Appendix 7). Although the fish did carry the disease, no outbreak occurred, and mortalities caused by ERM were minimal.

Mortalities attributed to coded wire tagging were also low considering the small size of fish marked -- about 1.5 g at SSP and 1.0 - 1.5 y at KC. Mortality due to coded wire tagging averaged about 0.2% at SSP and 0.4%, at KC for all fish.

Table 5. General linear models procedures (GLMP) and a Newman-Keuls multiple-range test using fork lengths of regular density treatments at Social Security Pond (SSP) and Rock Creek (RC), double and triple density treatments at Rock Creek and hatchery controls at Spring Creek National Fish Hatchery (SCNFH) (Treatments with the same grouping letter are not significantly different at the .05 level).

Summary of one-way GLMP (p=.05)

| Dependent variable | Source | d.f. | Type III SS | f-value | p>f |
|---|---|---|---|---|---|
| Fork length | treatment | 4 | 363.95 | 24.41 | .0001 |

Summary of multiple-range test

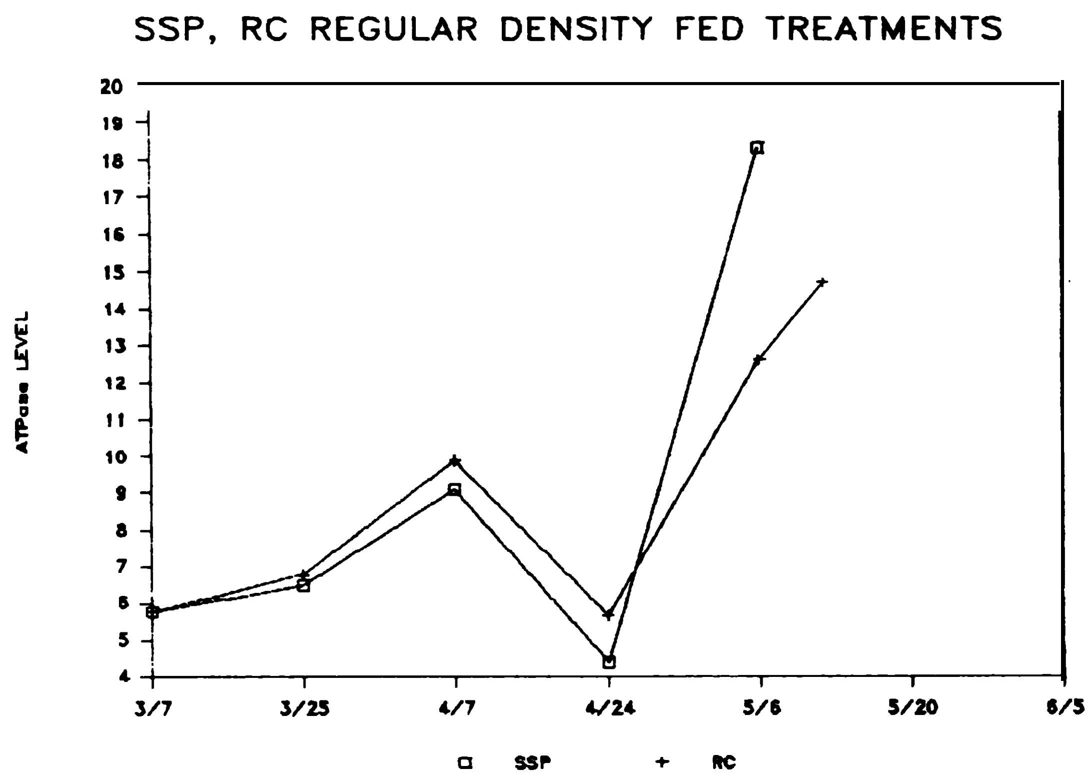
| Variable | Treatment | Mean Value | N | Grouping |
|---|---|---|---|---|
| Fork length | SSP | 76.36 | 50 | A |
| | RC (reg) | 75.61 | 31 | AB |
| | RC (double) | 73.87 | 30 | AB |
| | RC (triple) | 72.33 | 30 | B |
| | SCNFH | 64.98 | 40 | C |

Gill Na+-K+ ATPase levels of fish reared at regular density remained low at both locations, increasing toward the conclusion of the respective rearing periods (Fig. 4; Appendix d). Highest ATPase activities recorded for fish in regular density treatments were observed at release -- 18.3 micrornoles Pi/mg Prot/hr (units of activity) at SSP and 15.1 units of activity at RC.

Thyroxine ($T_4$) concentrations remained relatively stable over the initial phases of the rearing period, except at SSP where it rose sharply during the third week of April before decreasing during the following two weeks to levels near those observed in March (Fig. 5). The sharp increase noted at SSP did not occur at RC until the second week of May; highest thyroxine levels at RC occurred at release. Peak concentrations of thyroxine in fish reared in regular-density treatments were 12.4 ng/ml at SSP and 11.0 ng/ml at RC.

Cortisol levels were determined prior to transfer of fish from SCNFH to RC on f-larch 7. Levels were subsequently determined from fish during transfer, one day after transfer and one week after transfer to monitor effects of hauling, and to assess the recovery period. Initial values observed in the hatchery rose during transfer, but decreased by one day after transfer to a lower value than recorded before removal from the hatchery (Fig. 6). Values in these groups remained relatively low after two weeks of rearing.

Cortisol levels were also recorded before and after coded wire tagging at RC to assess any adverse stress which may have been associated with tagging fish on site. Values before and after tagging were similar, but increased after one week, and again, after one month



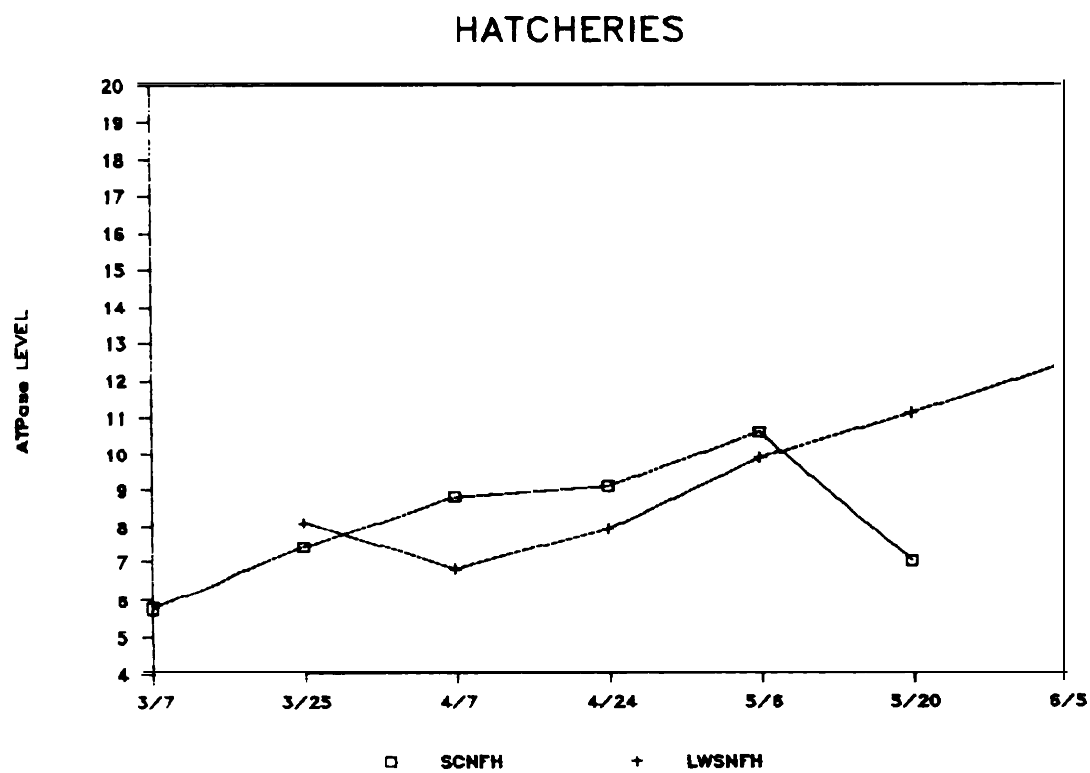
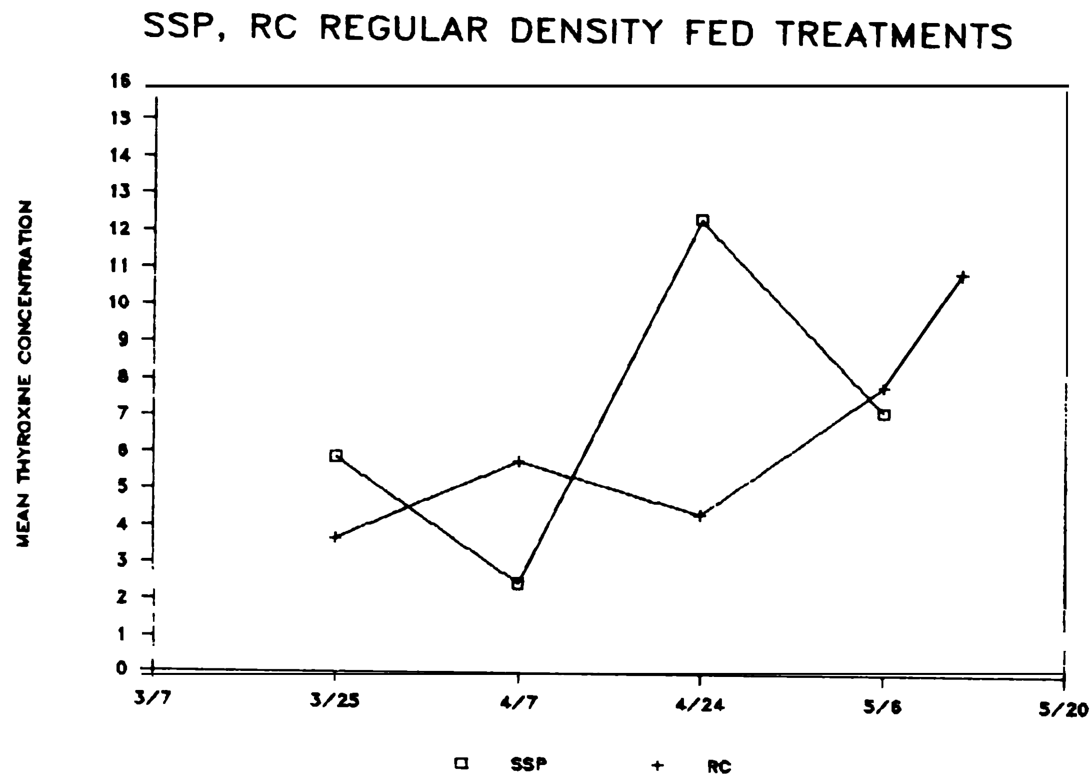




Figure 4. Gill $Na^+$-$K^+$ ATPase activity (micromoles Pi/mg prot/hr) of fed fish reared at regular density at Social Security Pond and Rock Creek and of fish reared at Spring Creek and Little White Salmon National Fish Hatcheries, 1986.



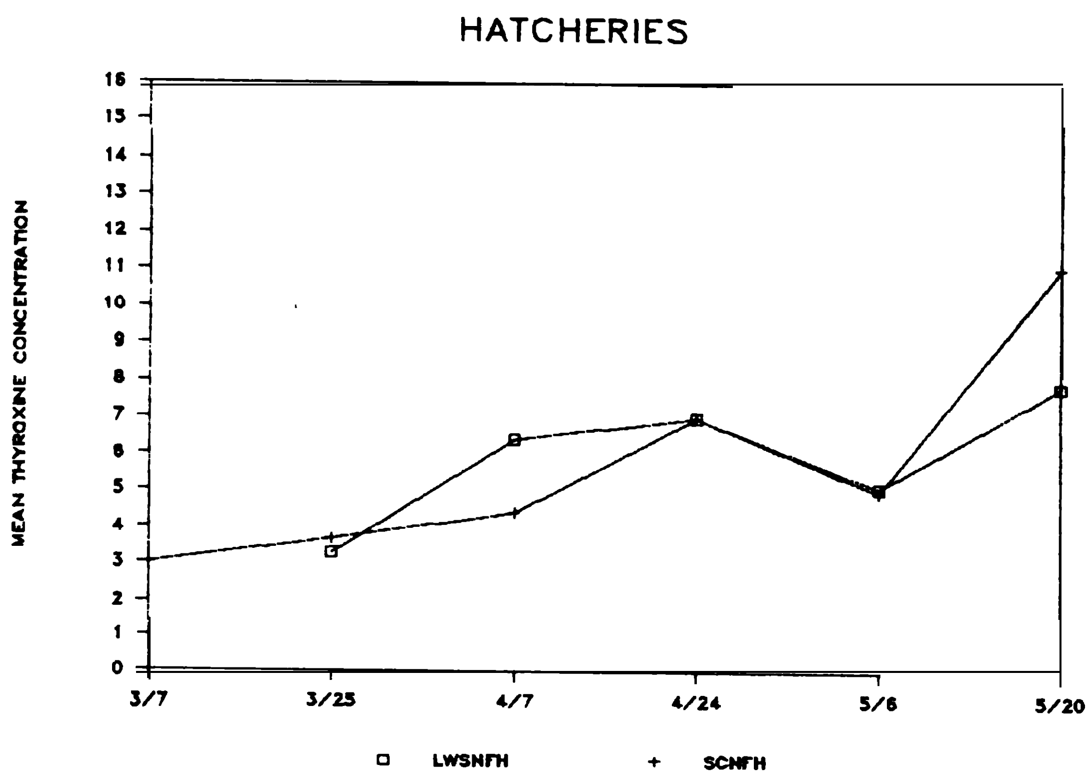




Figure 5. Blood serum thyroxine ($T_4$) concentrations (ng/ml) of fed fish reared at regular density at Social Security Pond and Rock Creek, and of fish reared at Spring Creek and Little White Salmon National Fish Hatcheries, 1986.

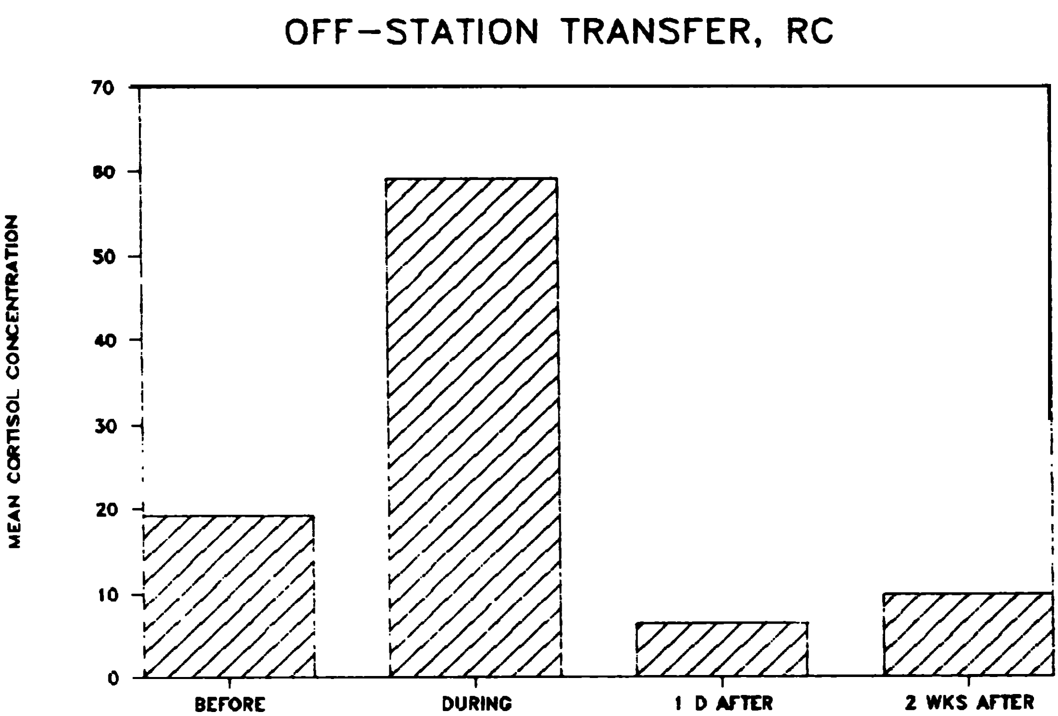



Figure 6. Blood serum cortisol concentrations (ng/ml) of fish transferred from Spring Creek National Fish Harchery to Rock Creek one day before transfer, during transfer, one day after transfer, and two weeks after transfer, 1986.

of rearing (Fig. 7). No samples were taken at SSP prior to tagging, however val ues after tagging were higher than observed at RC, increased to Over 40 ng/ml during the first week after tagging, and remained near 40 ng/ml after two weeks.

Blood-plasma Na+ levels of fish from RC exposed to SW were not significantly different (P>0.05) between trial two and three and were consistently lower than those of fish from SCNFH (Fig. 8). Plasma Na+ levels of fish from RC were lower than those of fish from SSP during trial two, but were not significantly different (P > 0.05) in trial three. Seawater mortality of fish from RC was <6% in both trials. Measured blood-plasma Na+ levels of S&exposed fish reared at SSP were the same as those from SCNFH (P > 0.05) during trial two, but declined in trial three and were then significantly lower (P < 0.05) than those of the hatchery fish. Mortalities were higher during trial two (22%) than trial three (2%), but the high mortality in trial two was due, in part, to a large number of mortalities (43%) in one replicate, presumably from causes other than SW exposure. Mortality in the other replicate was zero.

Fed Fish Reared in Pens at Double and Triple Density

Fed fish reared in double and triple density treatments were stocked at two and three times the density of regular density treatments (Table 4). Growth of these groups of fish was only slightly slower during the initial weeks than fish reared at regular density (Fig. 9). When regular-density fish were released on

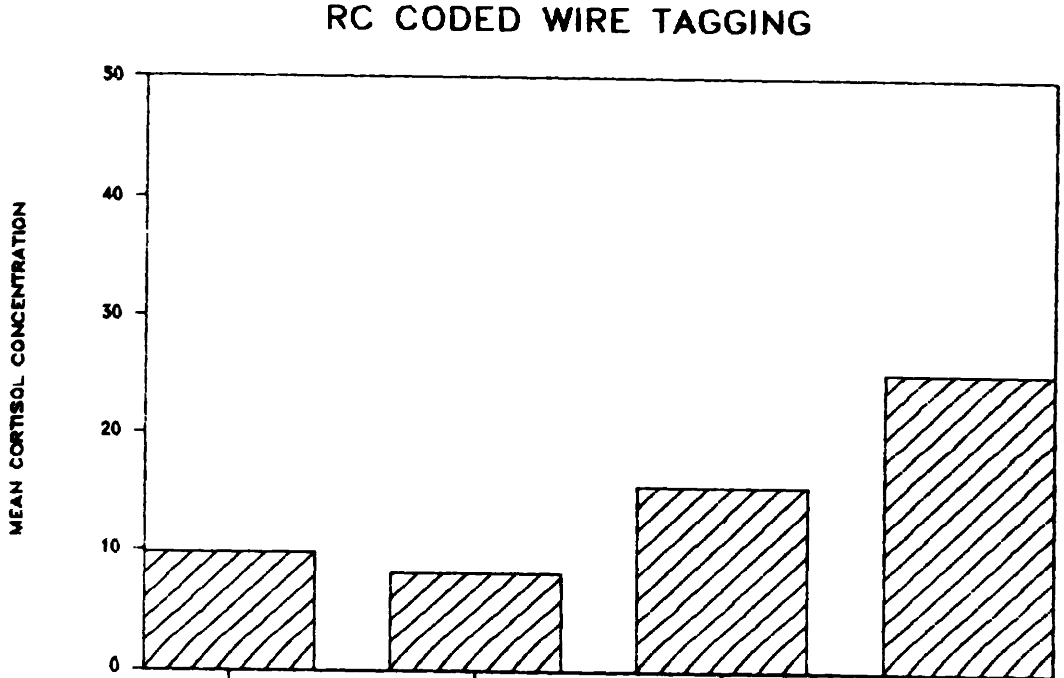
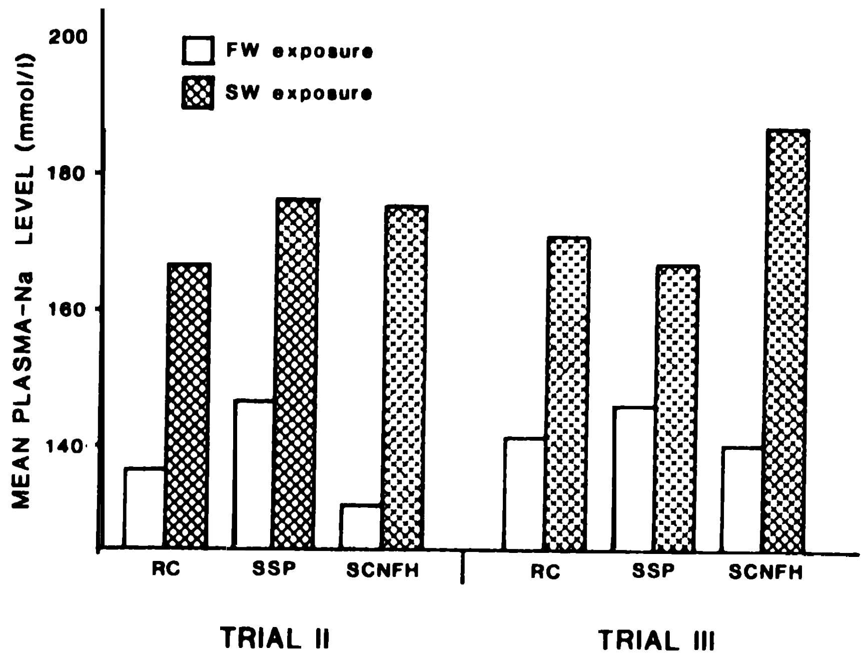



Figure 7. Blood serum cortisol concentrations (ng/ml) of fed fish reared at regular density at Rock Creek one day before, one day after, one week after, and one month after coded wire tagging, 1986.

## N-K ANALYSES




**TRIAL II**

**BETWEEN SITES**

| | | | |
|---|---|---|---|
| (FW) | SCNFH (146.3) | RC (137.0) | SSP (136.7) |
| (SW) | SSP (176.5) | SCNFH (175.2) | RC (167.3) |

**TRIAL III**

**BETWEEN SITES**

| | | | |
|---|---|---|---|
| (FW) | SSP (146.0) | RC (141.7) | SCNFH (140.1) |
| (SW) | SCNFH (187.3) | RC (171.1) | SSP (167.9) |

**BETWEEN TRIALS (SW)**

| | TRIAL II | TRIAL III |
|---|---|---|
| SSP | (176.5) | (167.9) |
| RC | (167.3) | (171.1) |
| SCNFH | (175.2) | (187.3) |

Figure 8. Results of seawater challenge, trials II and III, showing plasma-$Na^+$ levels in freshwater (FW) and seawater (SW) after 24 hours, and the summary of Newman-Keuls multiple range comparisons among sites, and between trials.

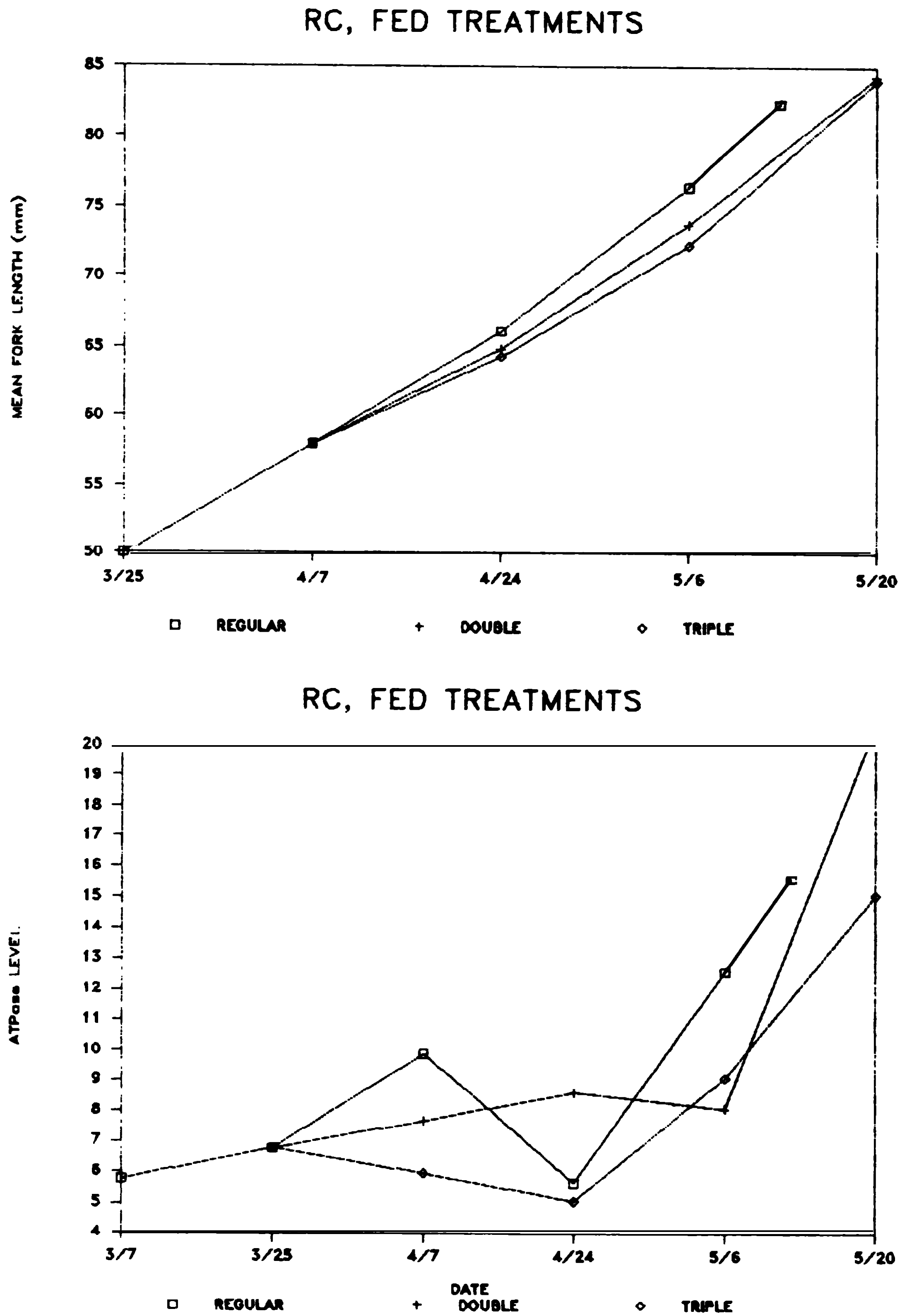



Figure 9. Growth (fork length) and gill $Na^{+}$-$K^{+}$ ATPase activity (micromoles $P_i$/mg prot/hr) of fed fish reared at regular, double, and triple density at Rock Creek, 1986.

May 14 the margin of difference among the fed treatments at RC was small, and not significantly different ($P > 0.05$)(Table 5). Fish reared in the hatchery were smaller throughout the rearing period than either of the higher density fed treatments.

Fish in double and triple density treatments were reared five days longer than those reared at regular density. Mean weight of fish at release was 6.5 g (69.8 fish/lb) and 6.3 g (72.1 fish/lb) for double and triple density treatments, respectively. Pounds of fish reared were about two and three times higher per pen than at regular density.

Survival of fish in all high density treatments was over 99.0%. The initial mortalities observed in the regular density treatments did not occur in high density treatments (Appendix 6). however, mortalities were somewhat higher toward the end of the rearing period when water temperatures spiked above 15.6° C.

Gill Na+-K+ ATPase activity remained relatively low in fish until mid-May and subsequently increased at release (Fig. Y). The highest ATPase levels observed in any of the groups of fish reared during 1986 were in double density treatments at release (20.7 units of activity; Appendix 8) ; highest ATPase activity in triple density treatments was 15.1 units of activity.

Thyroxine (T4) levels of fish reared at double and triple densities remained between 5-6 ng/ml during April (Fig. 10. During the first week of May, thyroxine levels of fish in both treatments increased, but levels increased more in triple density treatments. By the third week of May thyroxine levels in fish reared at triple density had receded, whereas the trend for those reared at double

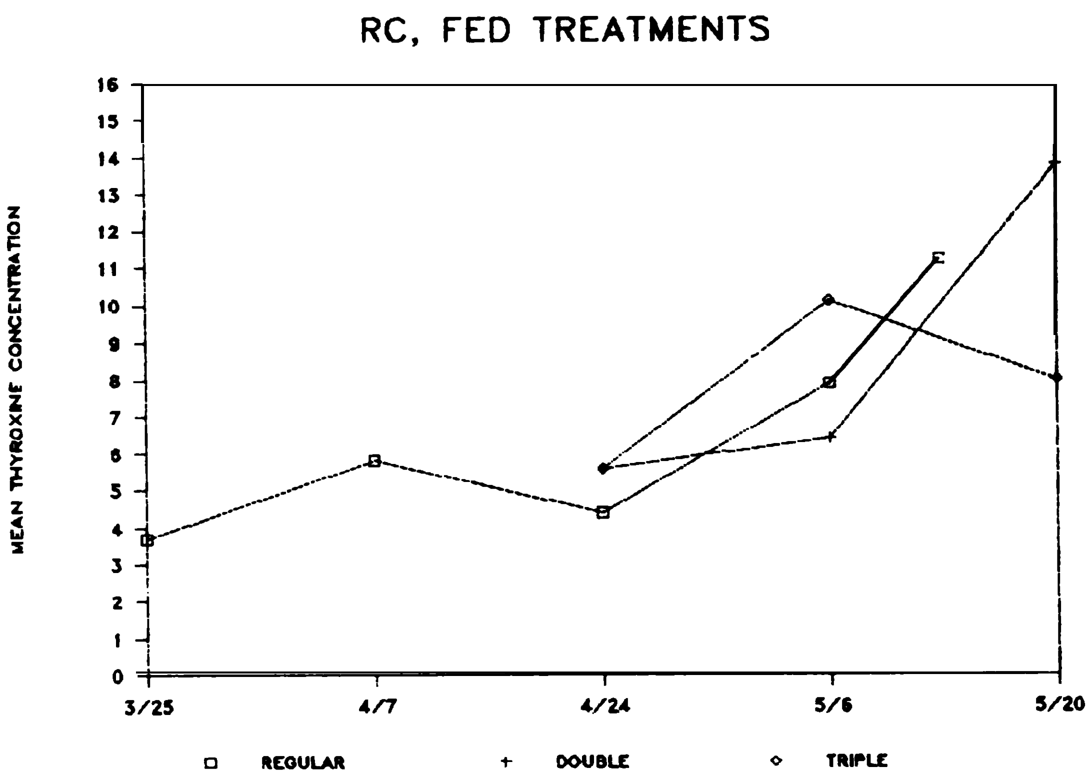



Figure 10. Blood serum thyroxine ($T_4$) concentrations of fish reared at regular, double, and triple density at Rock Creek, 1986.

density was similar to fish reared at reglar density, and had increased to the nighest levels recorded for any fish reared in the fed treatments.

Cortisol levels of fish in high density treatments were tested during the last week of April as a means of comparing stress induced by rearing the fish at higher densities. Fish at the hatchery and in regular density treatments at KC and SSP were al so tested during the same period (Fig. 11). Cortisol levels in fish reared at double and triple density were actually lower than those observed in fish reared at regular density at either SSP or RC, and only slightly higher than levels recorded in hatchery fish.

## Unfed Fish Reared in Pens

Fish reared in treatments with no food supplement were distributed among the various densities and replicates at a size of 2.3 g (200/lb) (Table 6). Mean numbers of fish stocked/pen in the three treatments resulted in the stocking of 967 fish (27.9 g/m3) at low density, 1652 fish (48.1 g/m3) at medium density, and 3702 fish (107.8 g/3) at high density; these fish were not coded wire tagged.

Unfed fish did not grow during the initial one or two weeks after stocking (Fig. 12). However, during the last week of April and first week of May, size of fish in low density treatments increased in fork length from 58.8 mm to 65.2 mm and in weight from l.92 g to 2.67 g Fish length in medium and high density unfed treatments increased slightly during the same period, while weights decreased. During the

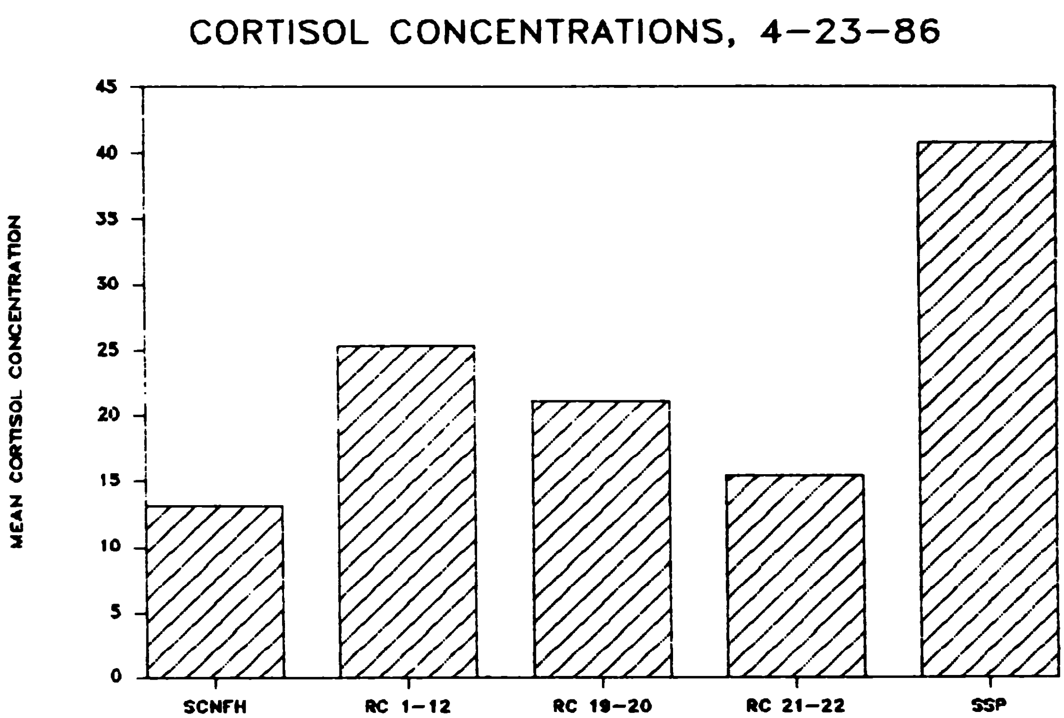



Figure 11. Blood serum cortisol concentrations (ng/ml) of fed fish at Rock Creek reared in all treatments, at Social Security Pond, and at Spring Creek National Fish Hatchery, April 23, 1986.

Table 6. Total number of fish stocked, mortality, number released and sizes and weights at release of unfed fish stocked in pens at densities of 32, 64, and 123 g /m3 (.002 .004, and .008 lb/ft3), and in a barrier net at 16 g/m3 (.001 lb/ft3), Rock Creek, 1986 (Individual pens are represented by groups letter A or B).

| | Density | | | | | | |
|---|---|---|---|---|---|---|---|
| | Low | | Medium | | High | | Barrier Net |
| Treatment summary | A | B | A | B | A | B | |
| **Stocking summary:** | | | | | | | |
| Number | 954 | 981 | 1814 | 1491 | 3468 | 3936 | 219,466 |
| Mean weight (g) | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 1.6 |
| Weight ($g/m^3$) | 27.7 | 28.6 | 52.8 | 43.4 | 100.9 | 114.6 | 20.2 |
| **Mortality:** | | | | | | | |
| Natural | 8 | 13 | 52 | 45 | 150 | 201 | 858 |
| (%) | (0.8) | (1.3) | (2.9) | (3.0) | (4.3) | (5.1) | (0.4) |
| Sample | 81 | 138 | 110 | 143 | 95 | 160 | 456 |
| **Release summary:** | | | | | | | |
| Number | 865 | 830 | 1652 | 1303 | 3223 | 3575 | 218,152 |
| Mean weight (g) | 2.8 | 3.2 | 2.7 | 2.6 | 2.1 | 2.0 | 2.0 |
| Number/lb | 162 | 141 | 167 | 178 | 217 | 230 | 232 |
| Weight ($g/m^3$) | 30.7 | 33.6 | 56.5 | 42.9 | 85.7 | 90.5 | 24.4 |

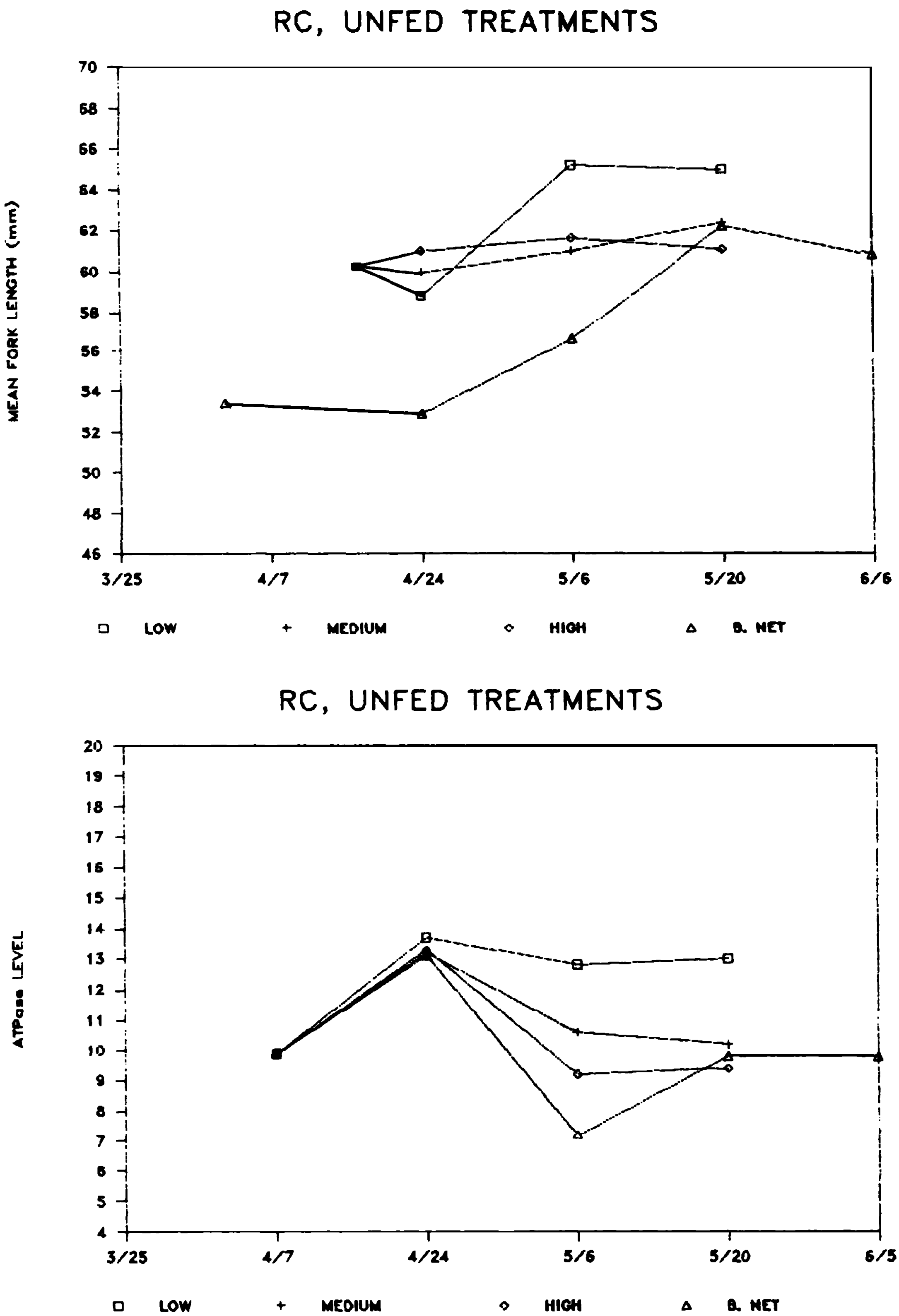



Figure 12. Growth (fork length) and gill $Na^+$-$K^+$ ATPase activity (micromoles $P_i$/mg prot/hr) of unfed fish reared in pens at low, medium, and high density, and of fish reared in the barrier net, Rock Creek, 1986.

final two or three weeks of rearing, differences among the three treatments increased, with low, medium, and high densities being largest (3.0 g), intermediate (2.6 g and smallest (2.0 g in mean weight, respectively.

Prior to release, hatchery fish were significantly larger ($P < 0.05$) than fish reared in any of the unfed treatments (Table 7). Fish reared at low and medium density were similar in size to unfed fish in the barrier net, while high density treatments were significantly smaller than low density treatments. When released, size differences of fish among all unfed treatments in pens were significantly different from one another ($P < 0.05$) (Table 7).

Highest mortalities (70) of fish observed in any of the treatments tested in 1986 occurred in unfed groups reared in pens; natural mortalities were 1.0 - 1.4% at low density, 2.9 - 3.2% at medium density, and 4.3 - 5.2% at high density (Table 6). Mortalities were not excessive over the rearing period in any treatment, but were somewhat higher during the initial and final phases of rearing (Appendix 6).

Gill $Na^+$-$K^+$ ATPase levels remained low throughout the rearing period (Fig. 12). Levels never exceeded 14 units of activity. ATPase levels determined on May 7 and 20 progressively increased from low to high density.

Highest thyroxine levels recorded from unfed fish occurred during the first two weeks in all treatments (Fig. 13). Thyroxine levels decreased and remained low, for all unfed fish during the remainder of the rearing period.

Table 7. Results of general linear models procedures (GLMP) and a Newman-Keuls multiple-range test using fork length of unfed treatments and the barrier net at KC on Ma 20 - live lengths (A) and on May 23 preserved lengths (B). (freatments with the same grouping letter are not different at the .05 level).

(A) Summary of one-way GLMP (p=.05)

| Dependent variable | Source | d.f. | Type III SS | f-value | p>f |
|---|---|---|---|---|---|
| Fork length | Treatment | 4 | 1899.62 | 13.68 | .0001 |

Summary of Newman-Keuls multiple-range test

| Variable | Treatment | Mean value | N | Grouping |
|---|---|---|---|---|
| Fork length | SCNFH | 69.69 | 42 | A |
| | Low | 65.04 | 28 | B |
| | Medium | 62.47 | 32 | BC |
| | B. Net | 62.25 | 61 | BC |
| | High | 61.16 | 31 | C |

(B) Summary of one-way GLMP (p=.05)

| Dependent variable | Source | d.f. | Type III SS | f-value | p>f |
|---|---|---|---|---|---|
| Fork length | Treatment | 2 | 787.06 | 32.51 | .0001 |
| | Pen (treatment) | 2 | 25.57 | 1.06 | .3507 |

Summary of Newman-Keuls multiple-range tests

| Variable | Treatment | Mean value | N | Grouping |
|---|---|---|---|---|
| Fork length | Low | 63.11 | 27 | A |
| | Medium | 59.57 | 54 | B |
| | High | 56.57 | 53 | C |

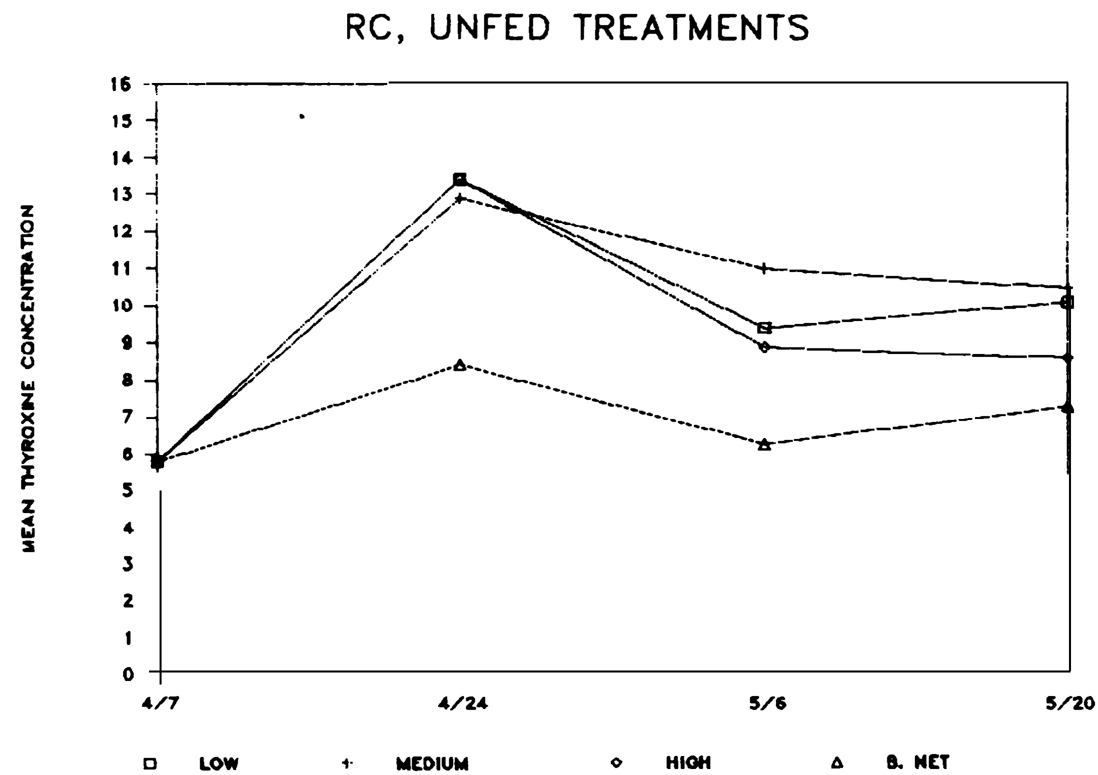



Figure 13. Blood serum thyroxine ($T_4$) concentrations (ng/ml) of unfed fish reared in pens at low, medium, and high densities and in the barrier net, Rock Creek, 1986.

Unfed Fish Reared in the Barrier Net

Four coded wire tagged groups totaling 219,466 fish at 276 fish/lb were stocked in the barrier net on April 5 and 7 (Table 6); density was 20.2 g/m3 (about 0.001 lb/ft3).

Estimated mortalities using a Peterson mark-recapture procedure were low in relation to numbers of fish originally stocked into the barrier net (Appendix g). Predators were removed prior to stocking with hopes of lowering the mortality rates observed in 1984 (30%) and l985 (49%). The number of potential predators removed from the enclosure, which was installed on February 21, was low, indicating that the early installation of the barrier net may have precluded the capture of predators prior to their movement into the area where the net was installed (Appendix 10).

Estimated numbers of the original fish stocked which remained in the barrier net at release ranged from 266,184 to 340,190 using 95% confidence limits and from 218,152 to 316,357 using 99.0% confidence limits. Since stocking density was about 220,000 fish, the low estimate (218,152) using 99.O% confidence limits was considered the most reasonable estimate of the population on June 4. Therefore, total natural mortality over the eight weeks of rearing was estimated at 0.4% (858 fish) for the barrier net in l986.

Growth of fish in the barrier net was poor throughout the rearing period (Fig. 12). However, growth was best from late April to the last week in May. Barrier net fish were similar in size on May 20 to fish in other unfed treatments ($P > 0.05$)(Table 7). Size of fish at release was 1.96 g (232 fish/lb), or less than 0.4 g larger than when stocked on April 5 and 7.

Gill ATPase activity of fish reared in the barrier net remained low, with little increase during the rearing period (Fig. 12). Activities were similar to those observed in 1985, and much lower than 1984 values. Thyroxine concentration fluctuated similarly to those values observed in other unfed treatments -- initially high, and decreasing during subsequent sampling periods (Fig. 13).

Examination for disease of fish reared in the barrier net detected no pathogens in late-April, but by release, enteric redmouth disease was present (Appendix 7). Water temperatures at the time were near 20° C at the surface, and about 14° C near the bottom. Mortality due to the disease did not cause significant losses over the course of the rearing period. A parasitic protozoan, Tricophyra sp., was also detected in gill filaments of barrier net fish at release. Infestation by these organisms was thought to be a source of irritation, but not a significant contribution to total mortality (personal communication, E. Pelton, Lower Columbia River Fish Health Center).

## Food Habits of Unfed Fish

Larval chironomids, zooplankton, and bryozoan statoblasts were the most abundant food items found in stomachs of unfed fish reared in net pens in 1985 (Table 8). Chironomid numbers in stomachs were inversely related to rearing density, i.e. percent of total numbers (TN) of chironomids in stomachs was highest in low density pens (81.5%), lowest

Table 8. Preliminary summary of major food items identified in stomachs of unfed fall chinook salmon during rearing in low, medium, and high density pens and a barrier net at Rock Creek, 1985.

| Treatment | Food Item | Mean No. per stomach | Percent Occurrence | Percent Number |
|---|---|---|---|---|
| Unfed Fish Low Density | Zooplankton | | | |
| | Copepoda | 5.7 | 70 | 6.9 |
| | Cladocera | 6.6 | 60 | 7.9 |
| | Insects | | | |
| | Chironomidae (Diptera) | 67.8 | 100 | 81.5 |
| | Other[a] | 1.3 | 20 | 1.5 |
| | Bryozoa | 1.8 | 60 | 2.2 |
| | TOTALS | 83.2 | | 100.0 |
| Unfed Fish Medium Density | Zooplankton | | | |
| | Copepoda | 2.1 | 70 | 9.2 |
| | Cladocera | 4.3 | 90 | 18.8 |
| | Insects | | | |
| | Chironomidae (Diptera) | 11.4 | 100 | 49.8 |
| | Other[a] | 1.3 | 60 | 5.6 |
| | Bryozoa | 3.8 | 70 | 16.6 |
| | TOTALS | 22.9 | | 100.0 |
| Unfed Fish High Density | Zooplankton | | | |
| | Copepoda | 1.9 | 50 | 10.6 |
| | Cladocera | 0.8 | 60 | 4.4 |
| | Insects | | | |
| | Chironomidae (Diptera) | 2.6 | 80 | 14.4 |
| | Other[a] | 0.4 | 60 | 2.8 |
| | Bryozoa | 10.9 | 80 | 60.6 |
| | Rocks and detritus | 1.3 | 10 | 7.2 |
| | TOTALS | 17.9 | | 100.0 |
| Barrier Net | Zooplankton | | | |
| | Copepoda | 36.4 | 62 | 54.8 |
| | Cladocera | 28.4 | 64 | 42.7 |
| | Insects | | | |
| | Chironomidae (Diptera) | 0.3 | 20 | 0.5 |
| | Other[a] | 0.5 | 42 | 0.7 |
| | Bryozoa | 0.6 | 18 | 0.9 |
| | Rocks and detritus | 0.2 | 18 | 0.4 |
| | TOTALS | 66.4 | | 100.0 |

[a] Coleoptera, Ephemeroptera, Hemiptera, Hymenoptera, Odonata, Unidentifed Diptera.

in high density pens (14.5%), and intermediate in medium density pens (50%) (Fig. 14).

Bryozoan statoblasts were consumed in the geatest numbers by fish reared in the high density pens (60% TN) and in progressively lower numbers by those from the medium (l7% TN) and low denisty pens (2% TN). Statoblasts were considered a low quality food item because the hard Outer covering of the organism does not appear to be readily digested.

Zooplankton consumed were directly proportional to rearing density, i.e. numbers consumed were highest in fish from high density pens and lowest in those reared in the low density pens. Zooplankton in stomachs from all densities was comprised primarily of cyclopoid copepods and the cladocerans Bosmina sp. and Daphnia sp.

Zooplankton was the most abundant food item utilized by fish reared in the barrier net, comprising over 95% of the total number of items per stomach (Fig. 14). Composition of the zooplankton was similar to that of stomachs examined from unfed fish in net pens. Neither chironomia larvae nor bryozoan statoblasts were common food items in stomachs of fish reared in the barrier net.

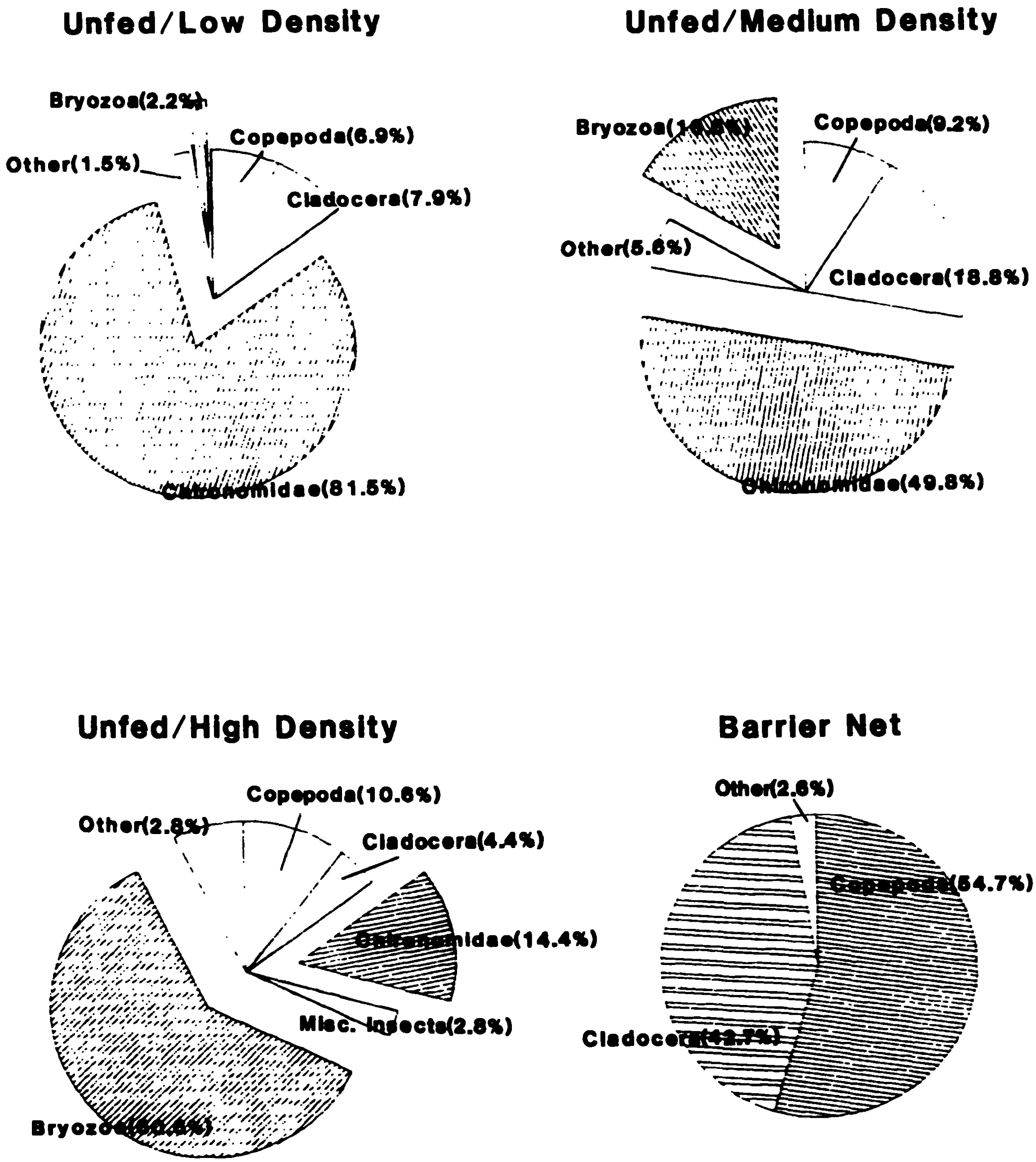



Figure 14. Percent of the total numbers of diet items eaten by unfed fish in pens reared at low, medium, and high densities, and in the barrier net, Rock Creek, 1985.

## Rearing and Release of Hatchery Fish

Control groups of fish were reared at SCNFH and LWSNFH. Fish at SCNFH were monitored for direct comparison of growth and physioloyical development with fish transferred to the off-station rearing sites whereas fish at LWSNFH were monitored and released for comparison with adult capture/return during future years. SCNFH fish were released at sites in the mid Columbia and lower Yakima rivers during the third week of June. Fish were released from LWSNFH on June 18th.

Growth of fish reared at SCNFH was somewhat faster than at LWSNFH (refer to Fig. 3). Water temperatures at both hatcheries remained stable and cooler (about 6.6-8.0° C at LWSNFH and about 11.5° C at SCNFH) throughout the rearing period than temperatures at the off-station sites. At release of regular density fed treatments, fish at SCNFH and LWSNFH were about 1.5 g smaller than groups at SSP (on May 5), and were between 3.0 g and 4.0 g smaller than regular density groups released at RC (on May 15). Double and triple density treatments were also larger at release (on May 20) than either of the hatchery control groups. However, unfed fish in all treatments were smaller at release than hatchery controls (refer to Figs. 3, Y, and 12).

Gill Na+-K+ ATPase activity remained low in fish over the rearing period at both hatcheries, although levels, especially at LWSNFH, appeared to rise gradually over the three-month period. Similar ATPase activity levels were observed in hatchery controls (SCNFH) in 1984 and in l985 (Fig. 15). Thyroxine (T4) concentrations rose slightly in mid-April, and again in mid-May (Fig. 5). These same trends were noted in regular density treatments at both sites, but at an earlier date.

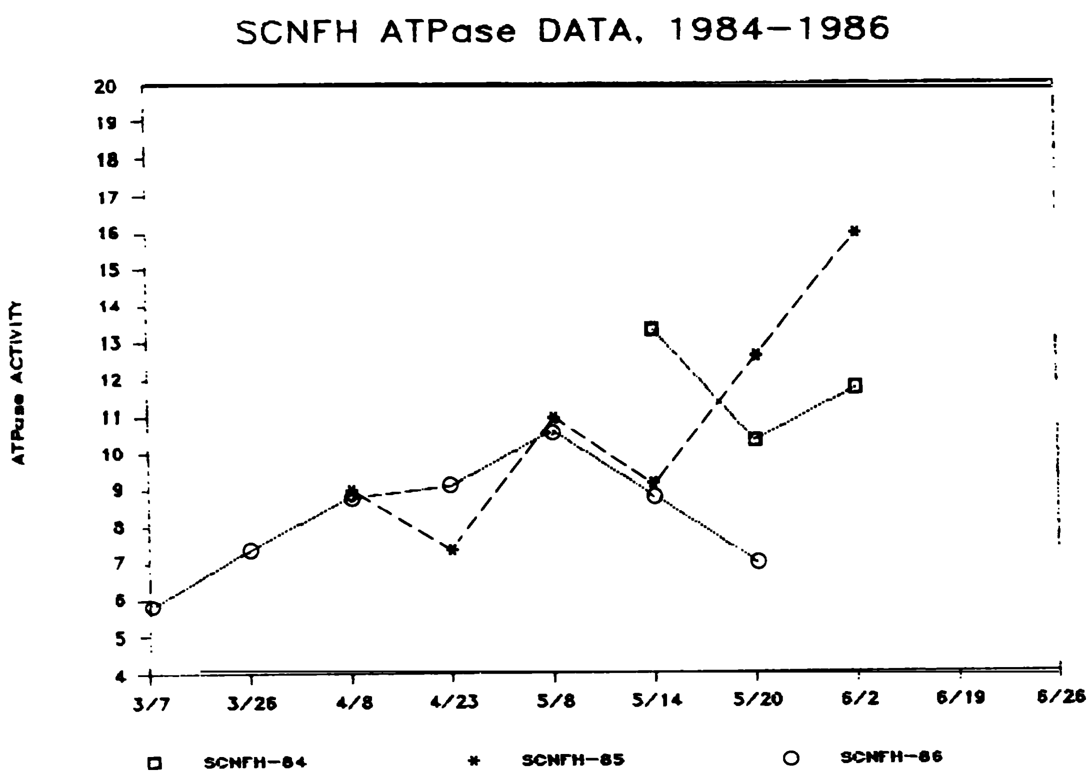



Figure 15. Gill $Na^+$-$K^+$ ATPase activity (micromoles $P_i$/mg prot/hr) of fish reared at Spring Creek National Fish Hatchery during 1984, 1985, and 1986.

Fish at SCNFH were treated for a minor outbreak of a protozoan infestation (Ichthyophthirius multifilis) in February, but an epizootic die-off did not occur (Ed LaMotte, mgr., SCNFH, personal communication). Fish at LWSNFH were exposed to a heavy silt load resulting in poor water quality in the stream source during early March, but no adverse effects were apparent during the remainder of the rearing period (E. Pelton, Lower Columbia Fish Health Center, personal communication).

## Utah Fish quality Indexing

The Utah Fish Quality Indexing methodology (Goede, In Press) was used as a further indication of effects various treatments might have on the health and general condition of fish reared off-station. Departure from normal, and in our case, departure from hatchery observations were considered to be effects of treatments manifest in the routine health observations. Results must be regarded as preliminary and are only presented at this point as a means of general comparison among treatments. Summaries of each autopsy for each group of fish are included in Apendices 11 to 16.

differences among fish from the various off-station treatments and the hatchery appeared primarily in condition factors, blood workups, and in the percentage of mesenteric fat present (Appendices 11 to 16). Mild inflamation of the thymus was observed to some degree in all groups. Liver observations of pink and pale color were both regarded as normal, considerin, that all I fish were bled prior to making other observations. Eyes, bills, pseudobranch, spleen, hind gut, kidney, and mesenter, observations were basically, normal for all groups.

Earliest observation of a group of fish was on March 7, prior to transfer from the hatchery. Condition factor, blood hematocrit, and serum protein were low at that point. Fish had been on hatchery food ration for only a short period and mesenteric fat had not begun to accuimlate. Over the remainder of the rearing period most observations of fish reared in the hatchery remained normal. However, mesenteric fat content tended to remain somewhat lower than desireable (< 50% of the pyloric caecum covered with fat).

Condition factors and blood chemistry of fish from regular density treatments at both sites were similar to those of hatchery fish during the rearing period. Mild hemorrhage (an indication of stress) was common in the thymus of both groups around the periods of redistribution among the pens at both sites, and for a period afterward. Mesenteric fat increased gradually during rearing of both groups.

Double and triple density treatments were quite similar to regular density treatments. Mild hemorrhage was prevalent in the thymus gland shortly after redistribution but decreased during later observations. Mesenteric fat, in general, was somewhat more prevalent in double and triple density treatments than either hatchery or regular density treatments.

Lowest condition factors of all treatments were observed among unfed fish reared at high density and barrier net fish. Blood hematorcrits is were similar in fed and unfed fish, but serum protein levels were lower for unfed fish than for fed fish, and gradually decreased during the rearing period. Lowest serum protein levels in any group were found in unfed fish reared at high density.

Mesenteric fat was either not present, or present in small amounts among all groups of unfed fish, especially toward the end of the rearing period. Mild hemorrhage of the thymus gland was observed during early observations among a few of the fish in all unfed treatments, but gradually improved over the remainder of the rearing period.

## Cost Estimates for Rearing Fish

Efficiency ratios (Senn et al. 1384) were developed for costs of rearing fed fish using the various methods attemped thus far, for rearing fish in a barrier net using the 1986 scenario, and for rearing fish in a concrete hatchery raceway, the facilities used at LWSNFH and SCNFH (Table 3; Appendix 17). The least costly method of rearing was in triple density treatments (0.27 lb/ft3) with a calculated efficiency ratio of $1.51/lb. Other densities used in net pens were proportionately less efficient (more costly) -- double density, $2.07/lb; regular density, $4.35/lb; and low density, $9.05/lb. Costs of rearing fish in the barrier net in 1986 ($27.12/lb) were much higher than any of the other treatments.

Regular, double, and triple density rearing expenses were lower than expenses of rearing fish in a concrete hatchery raceway ($5.73/lb). Rearing at low density in pens and in the barrier net using various study scenarios tested thus far were more costly, and much less efficient than hatchery rearing.

Table 9. Summary of expenses and efficiency ratios (Senn et al. 1984) calculated for rearing scenarios used thus far in pen rearing studies, and for comparable expenses for rearing fish in a hatchery raceway. Expenses calculated on basis of 1000 lb of fish at a size of at least 90/lb (5.0g) for net pens and hatchery. Costs of rearing supplies/expenses (in 1986 dollars) are listed in Appendix 17.

| | Expenses | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Method | Pond/ Facility | Plumbing | Water | Food | O&M[a] | Labor | Number Pens required/1000 lb. | Efficiency Ratio $/lb |
| Net pen - low density (.043 lb/ft$^3$) | 29,740 | 0 | 0 | 463 | 1485 | 2871 | 9.9 | 9.05 |
| Net pen - regular density (.086 lb/ft$^3$) | 13,218 | 0 | 0 | 533 | 660 | 1276 | 4.4 | 4.35 |
| Net pen - double density (.193 lb/ft$^3$) | 5,708 | 0 | 0 | 424 | 285 | 551 | 1.9 | 2.07 |
| Net pen - triple density (.270 lb/ft$^3$) | 3,905 | 0 | 0 | 381 | 195 | 377 | 1.3 | 1.51 |
| Barrier net (1.5 acre[b]) (.001 lb/ft$^3$) | 103,365 | 0 | 0 | 0 | 10,335 | ___ | 5.2 | 27.12 |
| Hatchery raceway | 6,440 | 6000 | 631 | 600 | 2350 | 835 | ___ | 5.73 |

[a] Operation and maintenance expense figured at 5% of capital investment for net pens, 10% for barrier net (including installation and removal), and $2.35/lb produced at the hatchery (J. Bodle, Complex Manager, Little White Salmon National Fish Hatchery).

[b] Barrier net expenses based on 1986 studies - - release size of 2.0g/fish and mortality of <1.0%.

## Adult Recovery

Trap nets and weirs were installed by mid-September at both Sites in anticipation of adult and Jack returns from the 1984 and 1985 releases. The 1984 release group will include three-year-old fish and the l985 release group gill include two-year-old fish (jacks). No results were available when the annual report of activities was submitted.

## DISCUSSION

Growth and survival of fed fish reared in pens in l986 was good in all groups at both rearing sites. Early transfer from the hatchery increased the rearing period by about four weeks, compared to 1985. Because of the early transfer, on-site tagging was necessary. However, tagging fish on-site, and at a small size (300-400/lb), was completed successfully, with very low mortality. The additional rearing time enabled the fish in fed treatments to reach a size of at least 90 fish/lb (5.0g) prior to release.

For the second consecutive year surface water temperatures increased markedly during April causing concern about the necessity of an early, premature release of fish at a small size. However, the temperatures cooled, and remained acceptable until the middle of May at both sites. Temperatures increased at SSP at a slightly faster rate than at RC requiring release of fish one week earlier than at RC.

Growth of fish reared and fed at SSP and KC was faster than for fish which were reared in the hatchery. Even though temperatures were slightly higher at SSP, the growtn of fish in regular density treatments at that site and at RC was similar during the respective rearing periods. dearing fish at densities two and three times greater than densities previously tested at RC did not result in growth Significantly different than that observed at regular density over the same rearing period. However, fish reared at souble density were larger than fish reared at triple density at release.

Fed fisn in all treatments underwent some physioloyical development during tne smoltification process, as indicated by the surge in thyraxi ne concentrations, rising gill ATPase activity, and the ability of fish (regular density treatments) to maintain blood sodium levels when challenged with a 24-h exposure to full-strength seawater. However, levels of smoltification for fish in tne respective red treatments had not reached peak levels by release, indicated primarily by the relatively low gill ATPase activities. Physiological development tor fish in all fed treatments proceeded at a faster rate than in hatchery fish, but a progressive rate of development was observed among fish at both hatcheries.

Mortalities Of fed fish in all treatmetns at both rearing sites were low, and health and general condition remained good during the rearing periods. Disease was not a problem among any of the fed treatments in 1986. Enteric redmouth disease was present in the original stock of fish when taken from the hatchery, but was not a cause of increased mortalities in the fed treatments. The additional week of rearing of high density treatments during warming water conditions did not appear to adversely affect fish health or condition.

Growth Of fish in Unfed treatments was poor during 1986, and they were significantly smaller at reledse than fish reared at the hatchery. Best growth of unfed fish was observed in low aensity treatments; growth at higher densities was Significantly poorer.

Physiological development was slowed, if not arrested, for fish in unfed treatments. An initial surge in thyroxine levels occurred shortly after distribution among the various unfed treatments, but neither coincidental, nor subsequent increases in gill ATPase activity were observed. The initial thyroxine surges were probably unrelated to smoltfication of unfed fish but more related to nutrient/density changes which took place when the fish were transferred from relatively nigh density holding pens where they were fed, to the unfed treatments, in Pens and the barrier net. The surge in thyroxine may nave been similar to what has been referred to as a "novel water" effect which results when fish are exposed to a unique stimulus (Dickoff et al. 1982, Nishioka 1985). The stimulus in our case would have been the exposure of the fish to extremely reduced densities and not feeding them.

Mortality of unfed fish was relatively low in all treatments, but mortalities increased progressively from low to high density. Removal of predators from the barrier net resulted in a dramatic decrease in mortalities from levels observed in previous years. disease was not a sigificant cause of mortality during tne rearing period in any of the unfed treatments.

General condition and healtn of unfed fish were poor in relation to fed fish. Condition factors and serum protein levels were lower and adipose tissue was much reduced, especially in high density/unfed treatments. These Observations were related to the low nutrient intake of unfed fish and tne presence of less desirable food items (statoblasts) in the diets of fish in high density/unfed treatments versus the presence, and apparent availability of larger food items (chironomids) in low sensity/unfed treatments. Adipose tissue deposited among the visera is a major storage reservoir in the body of the fish, and acts as the primary source of reserve energy (Jezierska et al. 1982). These tissues are the first to be catabolized during starvation (lager 1331).

By increasing the numbers of fish reared/pen in 1986 the total pounds produced were increased and cost estimates were lowered accordingly. Prelimiary efficiency ratios for al fed fish in pens were lower than estimated rearing costs in the hatchery.

Barrier net costs were excessively high based on the rearing scenario used in 1986. Even though mortalities were very low due to the removal of predators, growtn was poor,and pounds of fish produced per dollar expendd were low. Barrier net fish remained relatively heal thy over the rearing period but available food provided little more tnan a maintenance diet.

The food base of barrier net fish has been primarily zooplankton, while other unfed treatmetns, especially low density treatments, have relied on an apparently abundant chironomid food base. Therefore, in order to stimulte adequate growth of fish in the barrier net, either the density would have to be reduced to compensate for the low numbers of zooplankton available durign the early stages of the rearig period, or it would be necessary to feed tne fish, initially at least, and to gradually wean them form the hatchery food ration as zooplankton densities increase. By ComiJleting one or both of the above scenarios costs of rearing fish in the barrier net would be reduced, and may be competitive with other methods.

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Appendix 1. Tagging and retention summaries for fish coded wire tagged (cwt) and released at the Little White Salmon National Fish Hatchery, 1986. (Mortality includes total after tagginy for natural and sample mortalities).

| | | | | |
|---|---|---|---|---|
| Stocking Date | 6/18 | 6/18 | 6/18 | 6/18 |
| Code | 5-18-10 | 5-18-9 | 5-18-7 | 5-18-8 |
| Total tagged | 50,573 | 50,574 | 50,639 | 50,773 |
| Total Mortality | 264 | 264 | 188 | 188 |
| Total Released | 50,309 | 50,310 | 50,452 | 50,586 |
| Adipose clip/no cwt | 2,163 | 2,163 | 1,009 | 1,012 |
| | 48,146 | 48,147 | 49,443 | 49,574 |

**Appendix 2.** **tagging and retention summaries for fish coded wire tagged (cwt) and released at Rock Creek, 1986. (Mortality includes total after tagging for natural and sample mortalities).**

| | | | | |
|---|---|---|---|---|
| **Regular Density** | | | | |
| Stocking Date | 4/7/86 | 4/7/86 | 4/8/86 | 4/8/86 |
| Code | 5B-03-08 | 5B-03-09 | 5B-03-10 | 5B-03-11 |
| Total tagged | 55,180 | 55,243 | 55,040 | 55,421 |
| Total mortality | 1,700 | 1,700 | 564 | 564 |
| Total released | 53,480 | 53,543 | 54,476 | 54,857 |
| Adipose clip/no cwt | 2,209 | 2,212 | 1,779 | 1,792 |
| No clip/with cwt | 514 | 514 | 647 | 651 |
| No clip/no cwt | 0 | 0 | 54 | 54 |
| Total clipped/cwt released | 50,757 | 50,817 | 51,996 | 55,421 |
| **High Density** | Double | | Triple | |
| Stocking date | 4/3/86 | 4/3/86 | 4/3/86 | 4/3/86 |
| Code | 5B-04-09 | 5B-04-08 | B05-02-15 | B05-02-14 |
| Total tagged | 38,084 | 38,039 | 55,125 | 55,691 |
| Total mortality | 268 | 268 | 353 | 353 |
| Total released | 37,816 | 37,771 | 54,772 | 55,338 |
| Adipose clip/no cwt | 2,089 | 2,096 | 1,817 | 1,803 |
| No clip/with cwt | 300 | 299 | 216 | 218 |
| No clip/no cwt | 0 | 0 | 108 | 109 |
| Total clipped/cwt released | 35,427 | 35,376 | 52,631 | 53,208 |
| **Barrier Net** | | | | |
| Stocking date | 4/5/86 | 4/5/86 | 4/5/86 | 4/5/86 |
| Code | B5-02-13 | B5-02-12 | B5-02-11 | B5-02-10 |
| Total tagged | 55,005 | 55,300 | 55,005 | 55,004 |
| Total mortality | 540 | 543 | 540 | 540 |
| Total released | 54,465 | 54,757 | 54,465 | 54,464 |
| Adipose clip/no cwt | 2,124 | 2,136 | 2,124 | 2,124 |
| No clip/with cwt | 327 | 329 | 327 | 327 |
| No clip/no cwt | 163 | 164 | 163 | 163 |
| Total clipped/cwt released | 51,851 | 52,128 | 51,851 | 51,850 |

Appendix 3. TagginY and retention summaries for fish coded wire tagged (cwt) and released at Social Security Pond, 1986. (Mortality includes total after tagging for natural and sample mortalities).

| STOCKING DATE<br>CODE | 4/4&5<br>B5-03-12 | 4/2&3<br>B5-03-15 | 4/7&8<br>B5-03-14 | 4/5&6<br>B5-03-13 |
|---|---|---|---|---|
| Total tagged | 55,365 | 55,948 | 55,990 | 56,348 |
| Total mortality | 747 | 654 | 636 | 747 |
| Total released | 54,618 | 55,294 | 55,364 | 55,601 |
| Adipose clip/no cwt | 3,203 | 1,878 | 1,711 | 912 |
| No clip/with cwt | 493 | 470 | 604 | 91 |
| No clip/no cwt | 82 | 0 | 202 | 0 |
| Total clipped/cwt released | 50,840 | 52,946 | 52,387 | 54,598 |

Appendix 4. Chronology of events for rearing, trdnsfer, and release of upriver bright fall chinook salmon during pen-rearing studies, 1986.

| | |
|---|---|
| 9/l/85 - 9/30/85 | Adults captured in Bonneville Hatchery (Oregon Dept. of Fish and Wildlife) fish traps and fish ladder at Bonneville Dam. |
| 12/l/85 - 12/22/85 | Eggs taken at Bonneville Hatchery and transferred to Spring Creek and Little White Salmon National Fish Hatcheries. |
| l/l/86 - 3/l/86 | Fish reared and ponded at the hatcheries. |
| 3/7/86 - 3/14/86 | Fish transferred (at 550-650 fish/lb) from SCNFH to Rock Creek and Social Security Pond. |
| 3/10/86 - 3/25/86 | Fish marked (coded wire tagged) at Rock Creek as follows: Pens 1-6 - tag code 5B-03-08, 55,180 fish and tag code 5B-03-09, 55,243 fish; Pens 7-12 - tag code B5-03-10, 55,040 fish and tag code B5-03-11, 55,421 fish; Pens 19 & 20 - tag code 5B-04-08, 38,039 fish; Pens 21 & 22 - tag, code B05-02-15, 55,125 fish and tag code B05-02-14, 55,691 fish; Barrier net tag code B5-02-13, 55,005 fish, tag code B5-02-12, 55,300 fish, tag code B5-02-11, 55,005 fish, and tag code B5-02-10, 55,004 fish. |
| 3/31/86 - 4/7/86 | Fish marked (coded wire tagged) at Social Security Pond as follows: Pens 3,4,5 - tag code B5-03-12, 55,365 fish; Pens 6,7,8 - tag code B5-03-13, 56,348 fish; Pens 9,10,11 - tag code B5-03-14, 55,990 fish; Pens 1,2,12 - tag code B5-03-15, 55,948 fish. |
| 3/31/86 - 4/8/86 | Fish at Social Security Pond distributed among the 12 pens at required densities. |
| 4/3/86 - 4/4/86 | Fish distributed among various fed treatments at Rock Creek. |
| 4/7/86 | Fish released into the barrier net. |
| 4/12/86 | Fish distributed among various unfed treatments in pens at Rock Creek. |
| 3/25/86 - 6/5/86 | Growth, mortality, health, and physiological condition monitored in the hatcheries and in the various treatments at Rock Creek and Social Security Pond. |
| 5/6/83 | Fish at Social Security Pond released. |

Appendix 4 (cont.)

| | |
|---|---|
| S/13/86 | Fed fish held in pens at regular rearing density released at Rock Creek. |
| 5/20/86 | Fed fisn held in pens at two and three times regular density released at Rock Creek. |
| 5/29/86 | Fish held in pens (38,140) and released into the barrier net for mark-recapture estimate. |
| 6/4/86 | Fish released from the barrier net. |

Appendix 5. Summary of growth for all treatments using fork lengths (preserved samples) of fish reared at Social Security Pond and Rock Creek, 1986.

| Location | Enclosure | Date | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 3/25 | 4/15 | 4/29 | 5/15 | 5/20 | 5/29 | |
| RC | 1-12 | 44.7 | 55.7 | 64.5 | 75.3 | | | |
| RC | 19 | 44.7 | 56.9 | 63.6 | 80.6 | 82.1 | | |
| RC | 20 | 44.7 | 56.4 | 65.7 | 75.2 | 78.2 | | |
| RC | 21 | 44.7 | 57.2 | 63.1 | 73.8 | 77 | | |
| RC | 22 | 44.7 | 56.9 | 61.2 | 76 | 74.5 | | |
| RC | 13 | 44.7 | 56.2 | 51.6 | 57.4 | | | |
| RC | 14 | 44.7 | 56.2 | 56.6 | 60.9 | | 63.1 | |
| RC | 15 | 44.7 | 56.2 | 55.4 | 59.1 | | 60.2 | |
| RC | 16 | 44.7 | 56.2 | 56.6 | 57.6 | | 58.8 | |
| RC | 17 | 44.7 | 56.2 | 55.8 | 56.2 | | 56.6 | |
| RC | 18 | 44.7 | 56.2 | 54.1 | 58.5 | | 56.5 | |
| | | 3/25 | 4/7 | 4/15 | 4/30 | 5/15 | 5/29 | 6/4 |
| RC | B.Net | 44.7 | 48.5 | 50.4 | 52.3 | 57.6 | 58 | 59.3 |
| | | 3/28 | 4/11 | 4/24 | 5/6 | | | |
| SSP | 1-12 | 44.9 | 57.5 | 61.9 | 71.4 | | | |

Appendix 6. Weekly natural mortality of fish in pens at Social Security Pond and Rock Creek, 1986 after being split into respective treatments.

| ROCK CREEK | | DATE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Regular Density** | | 4/8 | 4/15&16 | 4/22 | 4/30 | 5/7 | 5/15&16 | 5/20-22 | 5/29 | Total |
| Pen Number | 1 | | 20 | 2 | 9 | 0 | 2 | | | 33 |
| | 2 | | 428 | 3 | 33 | 7 | 29 | | | 500 |
| | 3 | | 572 | 4 | 8 | 0 | 13 | | | 597 |
| | 4 | | 904 | 9 | 8 | 3 | 1 | | | 925 |
| | 5 | | 807 | 4 | 17 | 2 | 10 | | | 840 |
| | 6 | | 48 | 1 | 17 | 2 | 5 | | | 73 |
| | 7 | | 14 | 4 | 35 | 5 | 3 | | | 61 |
| | 8 | | 23 | 1 | 29 | 1 | 3 | | | 48 |
| | 9 | | 121 | 0 | 41 | 0 | 2 | | | 164 |
| | 10 | | 41 | 2 | 29 | 0 | 1 | | | 73 |
| | 11 | | 8 | 1 | 16 | 1 | 4 | | | 30 |
| | 12 | | 46 | 0 | 39 | 3 | 3 | | | 91 |
| **Unfed Fish** | | | | | | | | | | |
| Pen Number | 13 | | | 0 | 6 | 0 | 0 | 0 | 2 | 8 |
| | 14 | | | 4 | 5 | 0 | 0 | 0 | 4 | 13 |
| | 15 | | | 17 | 6 | 0 | 2 | 0 | 26 | 51 |
| | 16 | | | 20 | 19 | 0 | 1 | 0 | 13 | 44 |
| | 17 | | | 42 | 19 | 0 | 33 | 0 | 65 | 150 |
| | 18 | | | 1 | 69 | 0 | 0 | 0 | 61 | 131 |
| **Double Density** | | | | | | | | | | |
| Pen Number | 19 | 4 | 3 | 0 | 15 | 1 | 11 | 38 | | 72 |
| | 20 | 6 | 7 | 4 | 14 | 3 | 1 | 11 | | 46 |
| **Triple Density** | | | | | | | | | | |
| Pen Number | 21 | 9 | 1 | 1 | 17 | 0 | 18 | 104 | | 150 |
| | 22 | 8 | 7 | 2 | 83 | 1 | 3 | 31 | | 135 |

| SOCIAL SECURITY POND | | | | | | |
|---|---|---|---|---|---|---|
| Pen Number | | 4/11 | 4/20 | 4/28 | 5/6 | Total |
| | 1 | 176 | 0 | 10 | 3 | 189 |
| | 2 | 70 | 4 | 33 | 5 | 112 |
| | 3 | 46 | 0 | 18 | 1 | 65 |
| | 4 | 166 | 1 | 37 | 2 | 206 |
| | 5 | 117 | 0 | 23 | 1 | 141 |
| | 6 | 85 | 0 | 19 | 7 | 111 |
| | 7 | 114 | 0 | 47 | 1 | 162 |
| | 8 | 106 | 0 | 14 | 4 | 124 |
| | 9 | 88 | 0 | 16 | 3 | 107 |
| | 10 | 142 | 0 | 23 | 3 | 168 |
| | 11 | 61 | 0 | 13 | 1 | 75 |
| | 12 | 88 | 0 | 23 | 0 | 111 |

Appendix 7. Summary of health inspections completed on pen-reared fish by the Lower Columbia River Fish Health Center, Cook, WA., 1986.

| Date | Summary fi ndi ny |
|---|---|
| 4/22/86 | Five fish sampled from each pen at Rock Creek and from the barrier net. No pathoyens detected. |
| 4/24/85 | Five fish sampled from each pen at Social Security Pond. No pdthogens detected. |
| 5/15/86 | Five fish sampled from each regular density pen at Rock Creek at release. Enteric redmouth disease detected among fish examined. No other pathogens found. |
| 5/20/85 | Ten fish examined from double and triple density pens at release. No pathogens detected in double-density treatments; enteric redmouth disease detected in triple density treatments. |
| 6/4/86 | Ten - fifteen fish examined from barrier net at release. Enteric redmouth disease detected among fish examined. In addition, a parasitic protozoan, <u>Tricophyra</u> sp. was identified in the gill filaments of fish reared in the barrier net. |
| Note: | Prior to transfer from Spring Creek National Fish Hatchery, all fish used for stocking rearing enclosures at Rock Creek and Social Security Pond were routinely monitored by the Lower Columbia River Fish Health Center. |

Appendix 8. Gill $Na^+$-$K^+$ ATPase levels from pen rearing studies, 1986, expressed in micromoles $P_i$/mg prot/hr. (SCNFH-Spring Creek National Fish Hatchery, LWSNFH- Little White Salmon National Fish Hatchery, SSP-Social Security Pond, RC 1-Rock Creek - regular density, RC 2-double density, RC 3-triple density, RC 4-unfed/low density. RC 5-unfed/intermediate density RC 6-unfed/high density, RC B.N. - barrier net).

| Date | SCNFH | LWSNFH | SSP | RC 1 | RC 2 | RC 3 | RC 4 | RC 5 | RC 6 | RC B.N. |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/7 | 5.8 | | | | | | | | | |
| 3/24-28 | 7.4 | 8.1 | 6.5 | 6.8 | | | | | | |
| 4/7-10 | 8.8 | 6.8 | 9.1 | 9.9 | | | | | | |
| 4/21-25 | 9.1 | 7.9 | 4.4 | 5.7 | 8.6 | 5.1 | 13.7 | 13.2 | 13.3 | 13.1 |
| 4/29 | | | 8.2 | 5.1 | 5.7 | 5.5 | | | 6.8 | |
| 5/5-9 | 10.6 | 9.9 | 18.3 | 12.6 | 8.1 | 9.1 | 12.8 | 10.6 | 9.2 | 7.2 |
| 5/14 | | | | 15.1 | | | | | | |
| 5/19-22 | 7.0 | 11.1 | | | 20.7 | 15.1 | 13.0 | 10.2 | 9.4 | 9.8 |
| 5/4-5 | | 12.4 | | | | | | | | 9.8 |

**Appendix 9. Barrier net calculations and summaries including numbers of fish stocked and numbers of fish in the enclosure at release, 1986.**

---

**Summary:**

4/5 & 4/7/86 - 219,466 fish stocked in barrier net (220,314 minus 848 marking mortalities).

5/29/86 - 38,140 "marked" fish released into barrier net.[a]

6/4/86 - barrier net sampled with 100-ft seine for mark-recapture population estimate--3 hauls:

1) 121 unmarked and 44 marked
2) 1372 unmarked and 172 marked
3) 242 unmarked and 36 marked

---

Calculations:

a) Peterson formula (Chapman version) from Ricker (1975):

$$N = \frac{(M + 1)(C + 1)}{(R + 1)}$$

M = 38,140 (marked fish)
C = 1,988 (total fish seined)
R = 252 (marked fish seined)

b) $\frac{(38,140 + 1)(1,988 + 1)}{(252 + 1)}$ = 299,852 fish estimated to be in b. net at release

c) Confidence limits for R using 95% =
$(252 + 1.92 \pm 1.960\sqrt{252 + 1})$ = 223 and 285

Low and high estimates based on 95% confidence limits:

Low = $\frac{(38,140 + 1)(1988 + 1)}{285}$ = 266,184

High = $\frac{(38,140 + 1)(1988 + 1)}{223}$ = 340,190

d) Confidence limits for R using 99% =
$(252 + 3.32 \pm 2.576\sqrt{252 + 1})$ = 214 and 296

Low and high estimates based on 99.0% confidence limits:

Low = $\frac{(38,140 + 1)(1988 + 1)}{296}$ = 256,292 fish

High = $\frac{(38,140 + 1)(1988 + 1)}{214}$ = 354,497 fish

---

e) Actual number in barrier net on 6/4/86 was between 256,292 (lower confidence level at 99%) and 257,606 (total fish stocked)

f) 256,292 (low estimate fish in b. net on 6/4)
-38,140 (marked fish introduced on 5/29)
218,152 (total fish remaining in b. net on 6/4/86 from original groups stocked on 4/5 & 4/7/86).

219,466 (original number stocked)
218,152 (fish remaining in b. net on 6/4/86)
1,314 (total mortality over rearing period using low estimates of original population remaining in b. net at release)

Therefore: Estimated mortality in b. net in 1986 was <1% over rearing period.

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a/ "Marked" fish were fish witn no adipose fin clip.

Appendix 10. Summary of predator species removed from the barrier net, all methods combined, Rock Creek, 1986.

| Species | Size <100 mm | Size >100 mm |
| --- | --- | --- |
| White/Black Crappie | 139 | 0 |
| Bluegill | 473 | 2 |
| Pumpkinseed | 8 | 4 |
| Yellow Perch | 0 | 1 |
| Largemouth Bass | 9 | 7 |
| Smallmouth Bass | 1 | 0 |
| Total | 630 | 14 |

Appmdix 11. Summary of healtn indices of hatchery controls (Spring Creek Rational Fish Hatchery) during pen rearing studies, 1986, using tne Utah Fish Quality Indexing methodoloyy. (c.v. = coefficient of variation).

| Observation | 3/7 | 3/24 | 4/9 | 4/23 | 5/6 | 5/22 |
|---|---|---|---|---|---|---|
| Fork length (mm) | 42.2 | 49.2 | 54.4 | 57.3 | 61.8 | 68.4 |
| (c.v. --%) | (5.6) | (4.5) | (9.0) | (14.3) | (8.9) | (12.6) |
| Weight | 0.67 | 1.13 | 1.71 | 2.16 | 2.29 | 3.43 |
| (c.v. --%) | (17.7) | 16.7 | (29.3) | (42.4) | (29.1) | (39.4) |
| $K_{fl}$ | 0.87 | 0.94 | 1.03 | 1.07 | 0.94 | 1.01 |
| (c.v. --%) | (7.6) | (6.9) | 8.0 | (8.0) | (4.6) | (8.3) |
| Blood hematocrit | 30.9 | 33.0 | 35.6 | 36.4 | 38.0 | 39.6 |
| (c.v. --%) | (8.6) | (6.5) | (10.6) | (6.3) | (10.0) | (9.5) |
| Leucocrit | <1 | <1 | <1 | <1 | <1 | <1 |
| (c.v. 00%) | | - | | | | - |
| Serum protein | 5.1 | 5.6 | 5.5 | 6.4 | 6.0 | 6.2 |
| (c.v. --%) | (7.9) | (3.5) | (3.4) | (11.6) | (5.2) | (14.3) |
| Eyes | | | | | | |
| Normal (%) | 95 | 100 | 100 | 100 | 100 | 100 |
| Exopthalmia | 5 | 0 | 0 | 0 | 0 | 0 |
| Gills | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 |
| Pseudobranchs | | | | | | |
| Normal (%) | 100 | 100 | 95 | 85 | 100 | 65 |
| Inflamed/Swollen | 0 | 0 | 5 | 15 | 0 | 35 |
| Thymus | | | | | | |
| Normal (%) | 100 | 100 | 15 | 65 | 85 | 65 |
| Mild hemmorhage | 0 | 0 | 85 | 35 | 15 | 35 |
| Mesenteric fat | | | | | | |
| None | 100 | 65 | 0 | 0 | 0 | 25 |
| 1 - little | 0 | 35 | 100 | 100 | 85 | 75 |
| 2 - normal | 0 | 0 | 0 | 0 | 15 | 0 |
| 3 - above | 0 | 0 | 0 | 0 | 0 | 0 |
| Spleen | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 |
| Hind gut | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 |
| Mild inflammation | 0 | 0 | 0 | 0 | 0 | 0 |
| Kidney | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 |
| Liver | | | | | | |
| Normal (%) | 100 | 0 | 85 | 85 | 100 | 15 |
| Pale | 0 | 100 | 10 | 10 | 0 | 85 |
| Mesentery | | | | | | |
| Normal (%) | 100 | 100 | 100 | 80 | 80 | 100 |
| Mild inflammation | 0 | 0 | 0 | 20 | 20 | 0 |

Appendix 12. Summary of health indices of regular-density fed fish reared in pens using the Utah Fish Quality Indexing methodology, Social Security Pond, 1986. (c.v. = coefficient of variation)

| Observation | 3/28 | 4/7 | 4/24 | 5/6 |
|---|---|---|---|---|
| Fork length (mm) | 51.6 | 58.1 | 68.0 | 75.8 |
| (c.v. -- %) | (6.4) | (5.0) | (8.5) | (6.4) |
| Weight (g) | 1.26 | 2.04 | 3.41 | 4.02 |
| (c.v. -- %) | (20.9) | (17.3) | (28.3) | (19.7) |
| $K_{fl}$ | 0.90 | 1.04 | 1.05 | .91 |
| (c.v. -- %) | (6.9) | (7.2) | (8.6) | (5.3) |
| Blood hematocrit | 36.5 | 39.6 | 35.5 | 43 |
| (c.v. -- %) | (7.9) | (9.7) | (5.6) | (6.0) |
| Blood leucocrit | <1 | <1 | <1 | <1 |
| (c.v. -- %) | | | - | - |
| Serum protein | 5.8 | 6.7 | 6.0 | 5.7 |
| (c.v. -- %) | (6.0) | (13.0) | (5.7) | (11.3) |
| Eyes | | | | |
| Normal (%) | 100 | 100 | 100 | 100 |
| Gills | | | | |
| Normal (%) | 100 | 100 | 100 | 100 |
| Pseudobranchs | | | | |
| Normal (%) | 95 | 95 | 90 | 90 |
| Inflamed/swollen | 5 | 5 | 10 | 10 |
| Thymus | | | | |
| Normal | 30 | 25 | 75 | 80 |
| Mild hemorrhage | 70 | 75 | 25 | 20 |
| Mesenteric fat | | | | |
| None | 0 | 0 | 0 | 20 |
| 1-little | 95 | 90 | 55 | 60 |
| 2-normal | 5 | 10 | 45 | 20 |
| 3-above | 0 | 0 | 0 | 0 |
| Spleen | | | | |
| Normal (%) | 100 | 100 | 100 | 95 |
| Nodules present | 0 | 0 | 0 | 5 |
| Hind gut | | | | |
| Normal (%) | 95 | 100 | 100 | 100 |
| Mild inflammation | 5 | 0 | 0 | 0 |
| Kidney | | | | |
| Normal (%) | 100 | 100 | 100 | 100 |
| Liver | | | | |
| Normal (%) | 0 | 40 | 85 | 85 |
| Pale | 100 | 60 | 15 | 15 |
| Enlarged | 0 | 0 | 0 | 0 |
| Mesentery | | | | |
| Normal (%) | 100 | 100 | 85 | 85 |
| Mild inflammation | 0 | 0 | 15 | 15 |

Appendix 11). Summary of health indices of regular-density fed fish reared in pens using the Utah Fish Quality Indexing methodology, Rock Creek 1986 (C.V. = coefficient of variation).

| Observation | 3/25 | 4/10 | 4/22 | 5/6 | 5/14 |
|---|---|---|---|---|---|
| Fork length (mm) | 49.2 | 57.8 | 65.2 | 74.5 | 82.9 |
| (c.v. -- %) | (7.8) | (6.2) | (6.2) | (10.4) | (6.5) |
| Weight (g) | 1.23 | 2.26 | 2.93 | 4.37 | 6.22 |
| (c.v. -- %) | (21.6) | (20.8) | (18.9) | (32.6) | (20.7) |
| $K_{fl}$ | 1.02 | 1.16 | 1.05 | 1.02 | 1.08 |
| (c.v. -- %) | (7.4) | (6.3) | (6.1) | (6.2) | (5.3) |
| Blood hematocrit | 30.1 | 39.3 | 41.1 | 39.6 | 37.2 |
| (c.v. -- %) | (7.5) | (12.1) | (5.0) | (8.8) | (8.4) |
| Blood leucocrit | <1 | <1 | <1 | <1 | <1 |
| (c.v. -- %) | | - | - | - | - |
| Serum protein | 5.5 | 6.7 | 6.0 | 6.2 | 6.2 |
| (c.v. -- %) | (4.7) | (4.5) | (1.6) | (10.7) | (7.8) |
| Eyes | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 |
| Gills | | | | | |
| Normal (%) | 100 | 90 | 100 | 100 | 100 |
| Irritation | 0 | 10 | 0 | 0 | 0 |
| Pseudobranchs | | | | | |
| Normal (%) | 100 | 80 | 100 | 100 | 100 |
| Inflamed/swollen | 0 | 20 | 0 | 0 | 0 |
| Thymus | | | | | |
| Normal | 95 | 15 | 0 | 90 | 85 |
| Mild hemorrhage | 5 | 80 | 85 | 10 | 15 |
| Severe hemorrhage | 0 | 5 | 15 | 0 | 0 |
| Mesenteric fat | | | | | |
| None | 20 | 0 | 0 | 0 | 0 |
| 1-little | 80 | 85 | 85 | 45 | 15 |
| 2-normal | 0 | 15 | 15 | 50 | 60 |
| 3-above | 0 | 0 | 0 | 5 | 25 |
| Spleen | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 |
| Nodules present | 0 | 0 | 0 | 0 | 0 |
| Hind gut | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 |
| Kidney | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 |
| Liver | | | | | |
| Normal (%) | 0 | 100 | 100 | 100 | 40 |
| Pale | 100 | 0 | 0 | 0 | 55 |
| Enlarged | 0 | 0 | 0 | 0 | 5 |
| Mesentery | | | | | |
| Normal (%) | 100 | 100 | 100 | 95 | 100 |
| Mild inflammation | 0 | 0 | 0 | 5 | 0 |

Appendix 14. Summary of health indices of fed fish in high density fed pens using the Utah Fish Quality Indexing methodology, Rock Creek, 1986 (c.v = coefficient of variation).

| Observation | Double Density | | | Triple Density | | |
|---|---|---|---|---|---|---|
| | 4/21 | 5/5 | 5/20 | 4/21 | 5/5 | 5/20 |
| Fork length (mm) | 64.3 | 72.2 | 84.7 | 62.0 | 72.0 | 85.6 |
| (c.v. -- %) | (7.9) | (9.9) | (8.2) | (8.6) | (7.9) | (6.3) |
| Weight (g) | 3.06 | 4.21 | 6.52 | 2.65 | 4.18 | 6.42 |
| (c.v. -- %) | (23.7) | (28.7) | (26.3) | (26.6) | (24.4) | (20.2) |
| Kfl | 1.14 | 1.09 | 1.05 | 1.08 | 1.10 | 1.01 |
| (c.v. -- %) | (8.3) | (5.8) | (5.2) | (5.6) | (6.7) | (5.2) |
| Blood hematocrit | 41.8 | 38.1 | 41.8 | 42.2 | 35.9 | 43.4 |
| (c.v. -- %) | (9.0) | (8.3) | (8.1) | (8.5) | (7.2) | (8.9) |
| Leucocrit | 1.5 | <1 | <1 | <1 | <1 | <1 |
| (c.v. -- %) | (38.5) | - | | - | - | |
| Serum protein | 6.3 | 6.4 | 5.7 | 6.2 | 6.4 | 6.2 |
| (c.v. -- %) | (12.6) | (9.1) | (9.2) | (6.3) | (4.5) | (9.1) |
| Eyes | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 |
| Gills | | | | | | |
| Normal (%) | 95 | 100 | 100 | 100 | 100 | 100 |
| Frayed | 5 | 0 | 0 | 0 | 0 | 0 |
| Pseudobranchs | | | | | | |
| Normal (%) | 90 | 95 | 100 | 75 | 100 | 100 |
| Inflamed/swollen | 10 | 5 | 0 | 25 | 0 | 0 |
| Thymus | | | | | | |
| Normal | 20 | 80 | 80 | 15 | 70 | 85 |
| Mild hemorrhage | 75 | 20 | 20 | 85 | 30 | 15 |
| Severe hemorrhage | 5 | 0 | 0 | 0 | 0 | 0 |
| Mesenteric fat | | | | | | |
| None | 0 | 0 | 0 | 0 | 10 | 0 |
| 1-little | 75 | 45 | 40 | 90 | 65 | 30 |
| 2-normal | 25 | 55 | 55 | 10 | 25 | 70 |
| 3-above | 0 | 0 | 5 | 0 | 0 | 0 |
| Spleen | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 |
| Nodules present | 0 | 0 | 0 | 0 | 0 | 0 |
| Hind gut | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 |
| Kidney | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 |
| Liver | | | | | | |
| Normal (%) | 10 | 95 | 40 | 5 | 65 | 45 |
| Pale | 90 | 5 | 60 | 80 | 25 | 35 |
| Enlarged | 0 | 0 | 0 | 15 | 0 | 0 |
| Mesentery | | | | | | |
| Normal (%) | 95 | 100 | 100 | 65 | 95 | 100 |
| Mild inflammation | 5 | 0 | 0 | 35 | 5 | 0 |

Appendix 15. Summary of health indices of unfed fish in pens using the Utah Fish Quality Indexing methodology, Rock Creek, 1986. (c.v = coefficient of variation).

| Observation | Low Density | | | Medium Density | | | High Density | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4/22 | 5/5 | 5/21 | 4/22 | 5/5 | 5/21 | 4/22 | 5/5 | 5/21 |
| Fork length (mm) | 57.0 | 65.0 | 64.5 | 59.8 | 60.0 | 63.8 | 60.9 | 62.6 | 61.2 |
| (c.v. -- %) | (11.1) | (8.3) | (8.5) | (9.6) | (7.2) | (7.1) | (5.6) | (8.8) | (5.7) |
| Weight (g) | 1.80 | 2.66 | 2.42 | 2.01 | 1.86 | 2.34 | 2.13 | 2.11 | 1.86 |
| (c.v. -- %) | (29.7) | 23.8 | (23.5) | (30.5) | (20.0) | (19.7) | (17.6) | (28.8) | (16.2) |
| Kfl | 0.94 | 0.95 | 0.89 | 0.92 | 0.87 | 0.89 | 0.93 | 0.84 | 0.81 |
| (c.v. -- %) | (6.9) | (4.8) | (7.5) | (5.3) | (4.3) | (5.9) | (4.7) | (7.2) | (10.3) |
| Blood hematocrit | 37.8 | 38.9 | 39.7 | 41.5 | 39.7 | 40.4 | 39.6 | 39.7 | 40.4 |
| (c.v. -- %) | (5.1) | (6.4) | (5.0) | (3.1) | (6.5) | (7.5) | (3.2) | (3.1) | (4.8) |
| Leucocrit | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| (c.v. -- %) | - | - | | | | | | | |
| Serum protein | 5.2 | 5.2 | 4.7 | 5.1 | 4.4 | 4.3 | 5.0 | 4.2 | 3.5 |
| (c.v. -- %) | (5.4) | (6.2) | (6.8) | (9.8) | (3.6) | (7.0) | (5.3) | (10.1) | (15.3) |
| Eyes | | | | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Gills | | | | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Pseudobranchs | | | | | | | | | |
| Normal (%) | 83 | 100 | 100 | 85 | 100 | 100 | 95 | 100 | 100 |
| Inflamed/swollen | 17 | 0 | 0 | 15 | 0 | 0 | 5 | 0 | 0 |
| Thymus | | | | | | | | | |
| Normal (%) | 39 | 45 | 94 | 45 | 95 | 100 | 74 | 80 | 100 |
| Mild hemorrhage | 61 | 55 | 6 | 55 | 5 | 0 | 26 | 20 | 0 |
| Mesenteric fat | | | | | | | | | |
| None % | 28 | 20 | 100 | 15 | 100 | 90 | 5 | 30 | 100 |
| 1-little | 72 | 80 | 0 | 85 | 0 | 10 | 84 | 70 | 0 |
| 2-Normal | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 |
| 3-above | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spleen | | | | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Hind Gut | | | | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 85 | 100 | 100 | 100 | 100 |
| Mild inflammation | 0 | 0 | 0 | 0 | 15 | 0 | | | |
| Kidney | | | | | | | | | |
| Normal (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Liver | | | | | | | | | |
| Normal (%) | 44 | 0 | 100 | 50 | 95 | 80 | 26 | 0 | 70 |
| Pale | 50 | 100 | 0 | 50 | 0 | 20 | 74 | 95 | 30 |
| Enlarged | 6 | 0 | 0 | 0 | 5 | 0 | 0 | 5 | 0 |
| Mesentery | | | | | | | | | |
| Normal (%) | 89 | 100 | 94 | 100 | 85 | 70 | 100 | 100 | 65 |
| Mild inflammation | 11 | 0 | 6 | 0 | 15 | 30 | 0 | 0 | 35 |

Appendix 16. Summary of barrier net fish health indices using the Utah Fish Quality Indexing methodology, 1986 (C.V. = coefficient of variation).

| Observation | 4/25 | 5/9 | 5/22 | 6/4 |
|---|---|---|---|---|
| Fork length (mm) | 51.2 | 56.4 | 63.4 | 60.6 |
| (c.v. -- %) | (13.2) | (7.2) | (5.8) | (7.3) |
| Weight (g) | 1.18 | 1.70 | 2.16 | 1.88 |
| (c.v. -- %) | (42.8) | (21.8) | (15.6) | (20.6) |
| Kfl | 0.83 | 0.94 | 0.84 | 0.84 |
| (c.v. -- %) | (8.5) | (10.1) | (6.6) | (10.5) |
| Blood hematocrit | 32.2 | 37.6 | 39.1 | 38.1 |
| (c.v. -- %) | (2.6) | (6.1) | (5.5) | (4.6) |
| Blood leucocrit | <1 | <1 | <1 | <1 |
| (c.v. -- %) | | | | |
| Serum protein | 5.12 | 5.4 | 4.18 | 4.20 |
| (c.v. -- %) | (4.0) | (9.6) | (17.2) | (15.3) |
| Eyes | | | | |
| Normal (%) | 100 | 100 | 100 | 100 |
| Gills | | | | |
| Normal (%) | 100 | 100 | 100 | 100 |
| Pseudobranchs | | | | |
| Normal (%) | 65 | 100 | 90 | 100 |
| Swollen | 30 | 0 | 5 | 0 |
| Inflamed | 0 | 0 | 5 | 0 |
| Thymus | | | | |
| Normal | 85 | 85 | 95 | 100 |
| Mild hemorrhage | 15 | 15 | 5 | 0 |
| Mesenteric fat | | | | |
| None | 90 | 55 | 95 | 95 |
| 1-little | 10 | 45 | 5 | 5 |
| 2-normal | 0 | 0 | 0 | 0 |
| Spleen | | | | |
| Normal (%) | 100 | 100 | 100 | 100 |
| Hind gut | | | | |
| Normal (%) | 100 | 100 | 100 | 100 |
| Kidney | | | | |
| Normal (%) | 85 | 100 | 100 | 95 |
| Paled/granulated | 15 | 0 | 0 | 5 |
| Liver | | | | |
| Normal (%) | 75 | 0 | 95 | 100 |
| Pale | 25 | 95 | 5 | 0 |
| Focal discoloration | 0 | 5 | 5 | 0 |
| Mesentery | | | | |
| Normal (%) | 80 | 100 | 100 | 70 |
| Mildly inflamed | 10 | 0 | 0 | 30 |

Appendix 17. Summary of costs for rearing fish using the various methods tested in the present study, and costs of rearing fish in a concrete hatchery raceway. (Expected life of equipment/facility included in parentheses).

| | Cost |
|---|---|
| <u>Net Pen:</u> | |
| Fixed: | |
| Frame, anchors, buoys (20 y life) | $ 2,014 |
| Feeders (20 y life) | 415 |
| Nets, covers (7 y life) | 575 |
| | 3,004 |
| Variable: | |
| Food (Abernathy Dry @ .45/lb) | 400/pen (at .3 lb/ft$^3$) |
| Operation and maintenance (5% of capital investment) | 150 |
| Labor (.012 man-year/pen @ $25,000/year) | 290 |
| | 840 |
| <u>Barrier Net:</u> | |
| Fixed: | |
| Net - surface dimensions-225'X300'x225' (10 y life) | 15,032 |
| Anchoring chain - 20 lb/ft @ .20/lb x 750' (10 y life) | 3,000 |
| Floats - 10"x20"x9' @ $25/float (10 y life) | 2,000 |
| | 20,032 |
| Variable: | |
| Operations and maintenance (including installation and removal @ 10%) | 2,003 |
| <u>Hatchery (1000 lb of fish @ .5 lb/ft$^3$) [a]:</u> | |
| Fixed: | |
| Concrete raceway (50 y life) | 6,440 |
| Plumbing (25 y life) | 6,000 |
| Water | 631 |
| | 13,071 |
| Variable: | |
| Food cost (OMP @ .60/lb) | 600 |
| Operation and maintenance ($2.35/lb produced)[b] | 2,350 |
| Labor (.033 man-year/1000 lb @ $25,000/year) | 835 |
| | 3,785 |

[a] Senn et al. 1984

[b] Personal communication, J. Bodle, Little White Salmon National Fish Hatchery.

Summary of Expenditures (Direct costs), 1986

| | |
|---|---|
| Salaries/Benefits | $ 180,262 |
| Travel/Transportation | 21,556 |
| Non-expendable Equipment | 17,250 |
| Expendable Equipment | 23,656 |
| Operation and Maintenace (Consultants) | 6,091 |
| TOTAL | $ 254,815 |