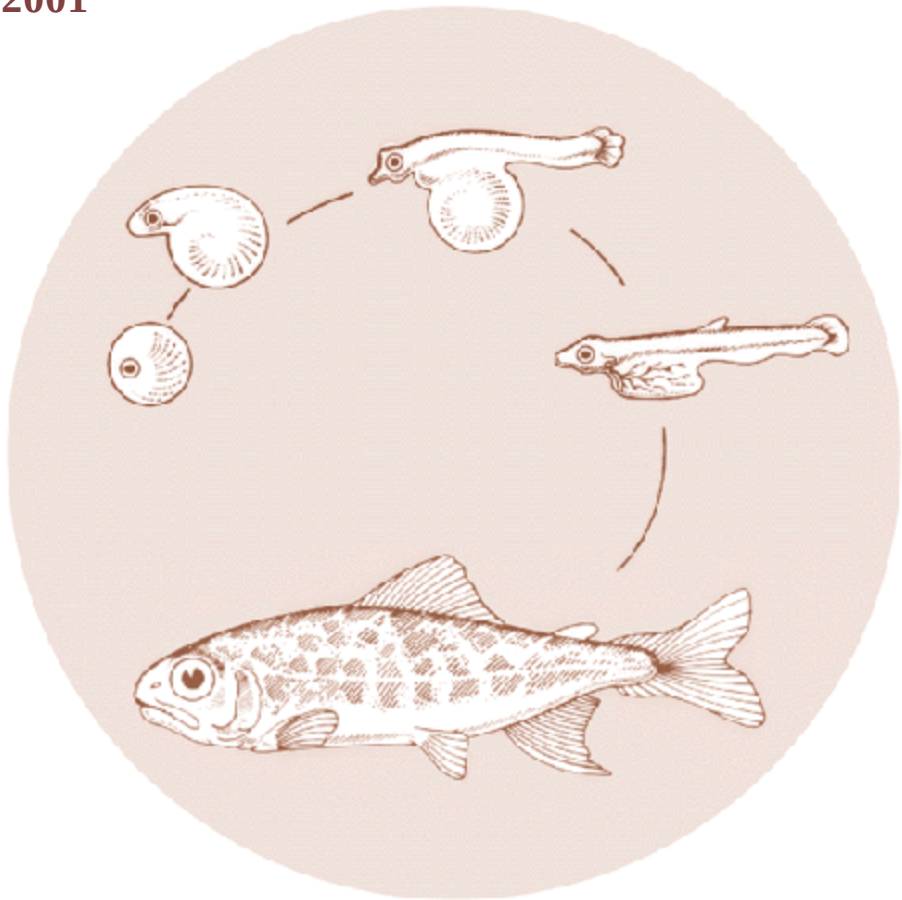
Captive Rearing Program for Salmon River Chinook Salmon

Annual Report
2001



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FISHERY RESEARCH

CAPTIVE REARING PROGRAM FOR SALMON RIVER CHINOOK SALMON

ANNUAL PROGRESS REPORT
January 1, 2001—December 31, 2001

Prepared by:

David A. Venditti, Senior Fisheries Research Biologist

Catherine Willard, Fisheries Research Biologist

Trisha Giambra, Fisheries Technician

Dan Baker, Fish Hatchery Manager

and

Paul Kline, Principal Fisheries Research Biologist

IDFG Report Number 03-33
October 2003

Captive Rearing Program for Salmon River Chinook Salmon

Project Progress Report

2001 Annual Report

By

David A. Venditti
Catherine Willard
Trisha Giambra
Dan Baker
Paul Kline

Idaho Department of Fish and Game
600 South Walnut Street
P.O. Box 25
Boise, ID 83707

To

U.S. Department of Energy
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Division of Fish and Wildlife
P.O. Box 3621
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ABSTRACT

During 2001, the Idaho Department of Fish and Game continued to develop techniques to rear chinook salmon *Oncorhynchus tshawytscha* to sexual maturity in captivity and to monitor their reproductive performance under natural conditions. Eyed-eggs were hydraulically collected from redds in the East Fork Salmon River (EFSR; N = 311) and the West Fork Yankee Fork Salmon River (WFYF; N = 272) to establish brood year 2001 culture cohorts. The eyed-eggs were incubated and reared by family group at the Eagle Fish Hatchery (Eagle). Juveniles collected the previous summer were PIT and elastomer tagged and vaccinated against vibrio *Vibrio* spp. and bacterial kidney disease prior to the majority of them being transferred to the National Marine Fisheries Service, Manchester Marine Experimental Station for saltwater rearing through maturity. Smolt transfers included 210 individuals from the Lemhi River (LEM), 242 from the WFYF, and 178 from the EFSR. Maturing fish transfers from Manchester to Eagle included 62 individuals from the LEM, 72 from the WFYF, and 27 from the EFSR. Additional water chilling capacity was added at Eagle in 2001 to test if spawn timing could be advanced by temperature manipulations, and adults from the LEM and WFYF were divided into chilled (≈ 9°C) and ambient (≈ 13.5°C) water temperature groups while at Eagle. Twenty-five mature females from the LEM (11 chilled, 14 ambient) were spawned in captivity with 23 males with the same temperature history in 2001. Water temperature group was not shown to affect the spawn timing of these females, but males did mature earlier. Egg survival to the eyed stage of development averaged 37.9% and did not differ significantly between the two temperature groups. A total of 8,154 eyed-eggs from these crosses were placed in in-stream incubators by personnel from the Shoshone-Bannock Tribe. Mature adults (N = 89) were released into the WFYF to evaluate their reproductive performance. After release, fish distributed themselves throughout the study section and displayed a progression of habitat associations and behavior consistent with progressing maturation and the onset of spawning. Five of the 18 redds spawned by captive-reared parents were hydraulically sampled to assess survival to the eyed stage of development. Eyed-eggs were collected from four of these, and survival to this stage ranged from 0%-89%. Expanding these results to the remaining redds produced an estimate of 15,000 eyed-eggs being produced by captive-reared fish.

Authors:

David A. Venditti
Senior Fisheries Research Biologist

Catherine Willard
Fisheries Research Biologist

Trisha Giambra
Fisheries Technician

Dan Baker
Fish Hatchery Manager

Paul Kline
Principal Fisheries Research Biologist

INTRODUCTION

Idaho Department of Fish and Game's (IDFG) long-term management objective for chinook salmon *Oncorhynchus tshawytscha* is to maintain Snake River salmon populations at levels that will provide sustainable harvest (IDFG 1996). Restoring currently depressed populations to historic levels is a prerequisite to this condition. Artificial propagation of spring and summer chinook salmon in the Salmon River basin through Lower Snake River Compensation Plan (LSRCP) and Idaho Power Company hatcheries was initiated to compensate for lost production and productivity caused by the construction and operation of private and federal hydroelectric facilities in the Snake River. The mitigation approach was to trap, spawn, and rear a portion of the historically productive local brood stock to produce a large number of smolts (Bowles 1993). When chinook salmon trapping began in 1981 as part of the LSRCP, it was assumed that enough chinook salmon adults would return to provide both harvest and continued hatchery production needs. It was also assumed that hatchery programs would not negatively affect the productivity or genetic viability of target or other populations and that natural populations would remain self-sustaining even with hydropower projects in place. In reality, smolt-to-adult survival in wild Snake River chinook salmon declined abruptly with completion of the federal hydroelectric system by the mid-1970s (Petrosky and Schaller 1994; Petrosky et al. 1999), and numbers of naturally produced salmon declined at various rates throughout the Snake River basin. It now appears the survival rate estimates used in the hatchery mitigation program models were substantially overestimated, which has led to hatchery programs that have been unable to mitigate for the loss of chinook salmon due to the dams or stem the decline of target populations. Spring/summer chinook salmon returns have been insufficient to meet artificial and natural smolt and adult production predictions, much less provide a consistent harvestable surplus of adults (Hassemer 1998).

Development of the Snake River hydrosystem has substantially influenced the decline of local spring/summer chinook salmon stocks by reducing productivity and survival (Raymond 1979; Schaller et al. 1999) and has contributed to the listing of Snake River chinook salmon under the Endangered Species Act (ESA; NMFS 1992). A recovery strategy incorporating natural-river function is most likely to increase the smolt to adult return rate and provide for recovery of these populations (Marmorek et al. 1998). However, until smolt-to-adult survival is increased, our challenge is to preserve the existing metapopulation structure (by preventing local or demographic extinctions) of these stocks to ensure they remain extant to benefit from future recovery actions. This program is developing technology that may be used in the recovery of the ESA listed Snake River spring/summer chinook salmon evolutionary significant unit (ESU), which consists of approximately 38 subpopulations (i.e. breeding units or stocks; NMFS 1995). Preserving the metapopulation structure of this ESU is consistent with the predecisional Snake River Salmon Recovery Plan (Schmitten et al. 1997, in review) and supports the Northwest Power Planning Council's goal of maintaining biological diversity while doubling salmon and steelhead *O. mykiss* runs (NPPC 1994).

Idaho and Oregon state, tribal, and federal fish managers met during 1993 and 1994 to discuss captive culture research and implementation in the Snake River basin. The outcome of those meetings was agreement that the Oregon Department of Fish and Wildlife (ODFW) would initiate a captive broodstock program using selected Grande Ronde River chinook salmon populations, and the IDFG would initiate captive rearing research using selected Salmon River chinook salmon populations. Both captive culture techniques begin by bringing naturally produced juveniles (eggs, parr, or smolts) into captivity and rearing them in a hatchery to sexual maturity. At this point, the two techniques diverge. Those in a captive-rearing program are

returned to their natal stream and allowed to spawn naturally. Those from a captive broodstock program are spawned in the hatchery where the resulting progeny are held until smoltification when they are released to emigrate volitionally. The primary focus of these programs was to evaluate the effectiveness of the two forms of captive culture to meet population conservation objectives. Implicit within each research project was the objective to develop and test appropriate facilities and fish culture protocols specific to the captive culture of chinook salmon for conservation management of depressed populations.

Little scientific information regarding captive culture techniques for wild-origin Pacific salmonids was available at the inception of these programs; available data was summarized by Flagg and Mahnken (1995). The IDFG captive rearing program was initiated to further the development of this technology by monitoring and evaluating captive-reared fish during rearing and post-release spawning phases. The Chinook Salmon Captive Propagation Technical Oversight Committee (CSCPTOC) was formed to convey new information between the various state, federal, and tribal entities involved in the captive culture of these fish. The CSCPTOC meets approximately every two months, which allows an adaptive management approach to all phases of the program and provides a forum of peer review and discussion for all activities and culture protocols associated with this program.

The IDFG captive rearing program was developed as a way to increase the number of breeding units and maintain metapopulation structure in selected populations at high risk of extinction, while avoiding the impacts of multigenerational hatchery culture described in Reisenbichler and Rubin (1999). The strategy of captive rearing is to prevent cohort collapse in the target populations by returning captive-reared adults to natural spawning areas to augment depressed natural escapement (or replace it in years when no natural escapement occurs). This maintains the continuum of generation-to-generation smolt production and provides the opportunity for population maintenance or increase should environmental conditions prove favorable for that cohort. However, this remains somewhat speculative because of uncertainties associated with the ability of the captive rearing approach to produce adults with the desired morphological, physiological, and behavioral attributes to successfully spawn in the wild (Fleming and Gross 1992, 1993; Joyce et al. 1993; Flagg and Mahnken 1995).

The IDFG captive rearing program was initiated in 1995 with the collection of brood year 1994 chinook salmon parr from three study streams. Since then, naturally spawned chinook salmon progeny from brood years 1995-2001 have been represented in captivity. Hassemer et al. (1999; 2001) and Venditti et al. (2002) summarize field and culture activities from the inception of the program through 2000. The streams selected for inclusion in the captive rearing program include the Lemhi River (LEM), the East Fork Salmon River (EFSR), and the West Fork Yankee Fork Salmon River (WFYF; Figure 1). Water quality is high in all three streams, and water temperatures are ideal for chinook salmon rearing. Habitat quality ranges from relatively pristine to areas of riparian degradation caused by sedimentation, grazing, mining, logging, road building, and irrigation diversion. The LEM drains productive basaltic parent material resulting in rapid fish growth. The lower section of this river flows through private land developed extensively for agriculture and grazing and typically reflects C channel conditions (Rosgen 1985). The EFSR drains a relatively sterile watershed of granitic parent material associated with the Idaho batholith. The lower 30 km of the EFSR runs through ranch and grazing property developed during the last century, but the upper reaches reflect near pristine conditions with little historical disturbance from logging, mining, or agriculture. Stream habitat in the EFSR typically reflects B and C conditions (Rosgen 1985). The WFYF, which drains a sterile watershed similar to the EFSR, remains primarily roadless and has remained nonimpacted by

land use practices for nearly half a century. Stream habitat typically reflects B and C conditions (Rosgen 1985).

Figure 1. Location of study streams included in the Idaho Department of Fish and Game Captive Rearing Program for Salmon River Chinook Salmon.

The goal of the captive rearing program is to evaluate the potential usefulness of the captive rearing concept as applied to the conservation of Snake River spring/summer chinook salmon. We have identified two primary project objectives needed to realize this goal. These are to: 1) develop and implement culture practices and facility modifications necessary to rear chinook salmon to adulthood in captivity having morphological, physiological, and behavioral characteristics similar to wild fish, and 2) evaluate the spawning behavior and success of captive-reared individuals under natural conditions. These objectives divide the program into two functional units including fish culture and field evaluations, but the success of the program is dependent on the synchronous development of both. This report documents activities performed in both aspects of the program during the period from January 1, 2001 through December 31, 2001. This program is coordinated with the Northwest Power Planning Council's Fish and Wildlife Program (NPPC 1994; 2000) and is identified as project 1997-00-100. Funding is provided through the Bonneville Power Administration.

METHODS

Culture Facilities

The IDFG Eagle Fish Hatchery (Eagle) is the primary Idaho site for the captive culture of program fish. The hatchery is supplied with pathogen-free artesian water from five wells, and the artesian flow is augmented with four separate pump and motor systems. Water temperature averages 13.5°C annually and total dissolved gas averages 100% saturation after degassing. Water chilling capability was added in 1994 and expanded in 2001 for use during various stages of the captive rearing process. Backup and system redundancy is in place for degassing, pumping, and power generation. Nine water level alarms are linked through an emergency service operator. Additional security is provided by limiting public access and by the presence of three on-site residences occupied by IDFG hatchery personnel.

Tanks of various sizes and configurations are maintained at Eagle to accommodate the various life stages and sizes of chinook salmon maintained on station. Fiberglass tanks ranging in size from 0.7 to 6.0 m in diameter are used to culture chinook salmon to maturity. After hatching, swim-up fry are transferred from incubators to 0.7 m semisquare tanks (0.09 m^3). Fish transfers between tanks are density related; fish are divided into multiple tanks and/or moved to larger tanks when densities reach 8.0 kg/m^3. Typically, juvenile chinook salmon will remain in 2.0 m (1.42 m^3) semisquare tanks until they are transferred, as smolts, to NOAA Fisheries Manchester Marine Experiment Station (Manchester) to be reared on saltwater. Returning mature adults from Manchester are placed in 3.0 m tanks (6.50 m^3) where they are held until release into natal waters or spawned at the hatchery. Flow to all tanks is maintained at no less than 1.5 exchanges per hour, and shade covering (70%) and jump screens are used where appropriate. Tank discharge standpipes are assembled in two sections ("half pipe principle") to prevent tank dewatering when removed for tank cleaning.

Tanks and culture facilities utilized by the chinook salmon captive rearing program are located in three general areas at Eagle. Spawning, incubation, and fry rearing take place in an enclosed building plumbed with chilled and ambient water, which allows water temperature regulation through controlled mixing. The intermediate sized tanks are located adjacent to the spawn building and also receive both chilled and ambient water. A roof covers tanks in this location, but the sides are not walled. The third group of tanks used by this program is located in a different area of the hatchery grounds approximately 100 m from the incubation building. The 3.0 and 6.0 m tanks are housed in this group, and are shielded from avian predators by a wire mesh enclosure. A metal roof has been constructed over the 6.0 m tanks to provide shade covering; however, the 3.0 m tanks are exposed to direct overhead and peripheral sunlight. A second water chiller was installed in 2001 to provide water temperature control to two of the 3.0 m tanks in this group; the other tanks receive ambient temperature water only.

Fish husbandry practices employed at Eagle range from traditional to experimental. Fish health issues are handled using only approved therapeutants, and standard fish culture practices are employed whenever possible (for an overview of standard methods see Leitritz and Lewis 1976; Piper et al. 1982; Erdahl 1994; Bromage and Roberts 1995; McDaniel et al. 1994; Pennell and Barton 1996). However, due to the experimental nature of the work conducted at Eagle, some aspects of the incubation, rearing, and feeding protocols vary from those used at production hatcheries. Eggs are hatched in specially designed incubators that allow siblings from individual spawn crosses or redds to be maintained separately, and this separation is maintained until after Passive Integrated Transponder (PIT) tagging (Prentice et al.

1990) to permit future familial identification. Rearing tank size, density, and food ration vary with fish age and are managed to promote optimum growth and to attain program objectives. Inventories are conducted periodically where fish are anesthetized, weighed to the nearest 0.1 g, and measured to the nearest 1 mm fork length (FL) to track growth and to ensure that projected weights track closely with actual weights. Fish are fed a standard commercial diet produced by Bio-Oregon, Inc. (Warrenton, Oregon) until they reach approximately 160.0 g, after which time they receive a special brood diet enhanced with natural flavors from fish and krill.

Saltwater rearing is provided for the majority of study animals post smoltification at Manchester. This facility is located on Puget Sound near Seattle, Washington, and is supplied with approximately 5,000 L/min (1,320 g/min) of saltwater that averages 29$^{o}/_{oo}$ salinity and temperature ranging from 7.0 to 14.0°C. Raw saltwater is passed through sand and cartridge filters to remove particles >5 μ, sanitized with ultraviolet light, and degassed prior to entering fish rearing tanks. Effluent from the rearing tanks is sanitized with ozone treatment prior to being returned to Puget Sound (Frost et al. 2002). Immature chinook salmon are held in 4.1 or 6.0 m diameter tanks until maturity.

Eyed-Egg Collection, Transport, and Incubation

Eyed-eggs to establish captive cohorts were collected from redds spawned by wild chinook salmon in the WFYF and the EFSR using hydraulic sampling methods described by McNeil (1964). The hydraulic sampling system consisted of two main components. The first is a gas-powered pump attached to a 3.8 cm diameter aluminum probe, via flexible tubing (Figure 2). Holes drilled near the top of the probe infuse air into the water stream through venturi action. The second component is the collection net frame, which consists of a “D” shaped aluminum frame with expanded plastic mesh along its curved portion and netting around the bottom and sides of its straight portion (Figure 2). When the pump is on, water is forced through the probe, which is worked into the substrate. The air/water stream then lifts eggs out of the substrate, where they are swept downstream into the net. The expanded plastic screen confines eggs lifted out near the periphery and channels them into the net. In order to minimize disturbance to the redd, sampling is generally started slightly downstream of estimated nest pocket locations and progresses upstream. This procedure prevents the fine materials lifted out of the substrate from settling back into the redd and possibly smothering the eggs. Care is also taken to keep personnel behind or to the side of the net frame to minimize redd disturbance.

To facilitate eyed-egg collections, redd locations are marked, construction and completion dates are determined, and stream temperatures are monitored with recording thermographs. When the redd is completed and the female no longer present, rocks are wrapped with orange flagging and placed in the stream bed just upstream of the pit and downstream of the pillow along the central axis of the redd. This arrangement helps locate the redd and identifies the most productive sampling locations even if algal growth has obscured it. Thermographs deployed in the study streams record water temperature at 2 h intervals, and daily average water temperature is computed to track the number of Celsius temperature units (CTUs) received by the developing embryos in each stream. Eyed-eggs are collected when they have received 300-400 CTUs. At this point eye pigmentation makes developing embryos readily identifiable and eggs are capable of withstanding collection.

Eyed-eggs are transferred from collection locations to Eagle using the following standardized protocols. Eyed-eggs are packed at a conservative density in perforated shipping tubes, capped, and labeled to identify them to stream and redd. Tubes are wrapped in paper

towels saturated with river water and packed in small, insulated coolers. Ice chips are added to maintain proper temperature and a moist environment during transport. Eggs are taken to Eagle as soon as possible after collection and are generally on site 4–6 h after being extracted from the gravel.

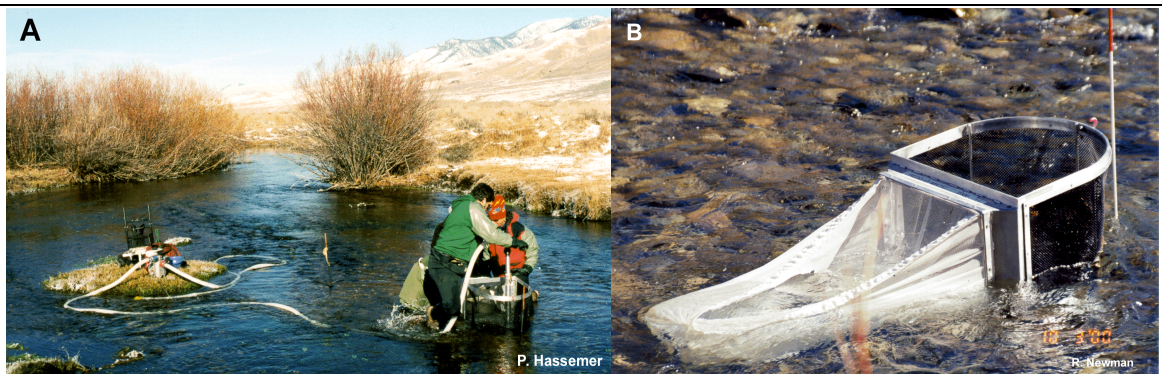

Figure 2. Hydraulic sampling gear including (A) the pump and probe, and (B) the collection net used to collect eyed-eggs from naturally spawned redds.

Once at Eagle, familial groups of eyed-eggs are transferred to separate incubators (14 cm diameter x 19 cm height, 2.35 L total operating volume) where they remain until the resulting fry are ready to begin feeding. A constant flow (2 L/min) of chilled water (8.0–10.0°C) is maintained throughout incubation and is provided as upwelling from below the eggs (Figure 3, diagram A). Incubators are checked daily, and dead eggs removed. After hatching, water flow is reversed (Figure 3, diagram B).

Juvenile Rearing, Marking, and Transportation

After ponding, chinook salmon fry are reared in 1 m semisquare tanks, and individual familial groups are maintained separately. Tanks receive a mixture of ambient and chilled water that maintains temperatures at 8.0–10.0°C and ensures approximately 1.5 water exchanges/hour. Fry are fed a commercial diet (Bio-Oregon Starter #2) at approximately 2.0% body weight per day. As fish grow, ration and pellet size are adjusted accordingly.

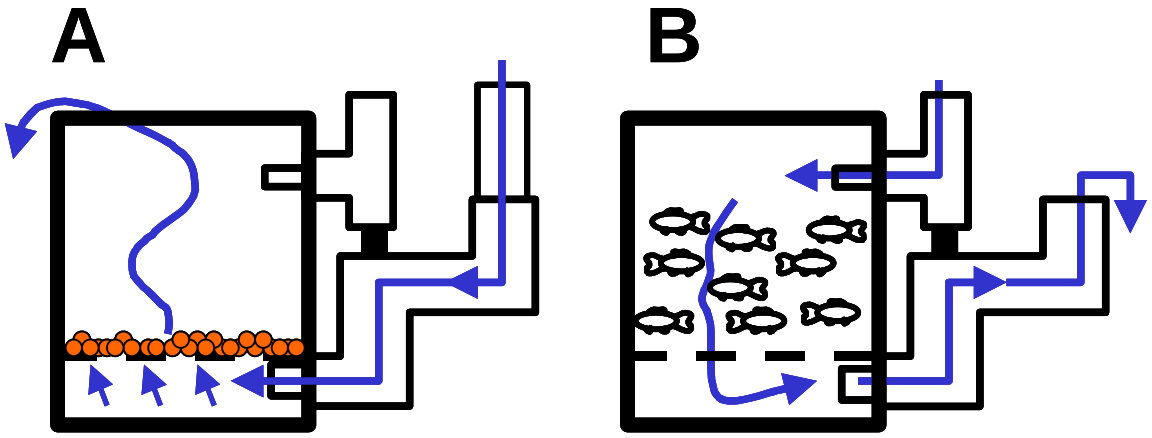

Figure 3. Schematic diagram of reversible flow incubators used to incubate eggs and rear newly emerged fry. A) Upwelling configuration for egg incubation, and B) downwelling configuration for fry rearing.

Swim-up fry are fed for one week in the incubators prior to ponding to 0.7 m semisquare tanks. Fry are fed hourly during daylight hours, approximately eight times per day until they reach 1.0 gram. Growth projections are developed at this time and feeding rates are reduced to four times per day. Fish sample counts are conducted as needed to ensure actual growth tracks the projected growth rate. In general, fish are handled as little as possible. Age-1 and age-2 chinook salmon rearing densities are maintained at levels not to exceed 8.0 kg/m^3. Age-3 and age-4 rearing densities are maintained at levels not to exceed 14.0 kg/m^3.

Incubation and rearing water is maintained between 8.0°C and 13.5°C. This is accomplished by mixing chilled water (7.0°C) with ambient water (13.5°C). This allows the program to equalize development and growth differences that may result from a protracted spawning period. Chinook salmon are typically placed on chilled water to slow growth rates and better mimic natural conditions.

Juvenile chinook salmon are marked during two separate events at Eagle each year to aid in tracking fish in the program. The first involves injecting a PIT tag into the peritoneal cavity of age-0 juveniles. Fish are anesthetized in MS-222 (tricaine methanesulfonate; buffered to neutrality with sodium bicarbonate), weighed to the nearest 0.1 g and measured to the nearest 1 mm FL. A modified 12-gauge hypodermic needle is then used to inject the PIT tag into the body cavity slightly anterior to the pelvic girdle and just off the ventral midline. The PIT tag gives each individual a unique identity within the program and is used to track each fish through the remainder of its life. The second marking involves age-1 juveniles and is conducted shortly before their transfer to Manchester. Fish are anesthetized in buffered MS-222 and a color-coded elastomer tag, based on stream origin, is injected into the clear tissue immediately posterior to the eye (Olsen and Vøllestad 2001; Close and Jones 2002). Fish from the EFSR and WFYF receive green and orange marks, respectively. Additionally, fish receive interperitoneal vaccinations of Renogen *Arthrobacter sp*. as a prophylactic against bacterial kidney disease (BKD) and Vibrogen to vaccinate against *Vibrio* spp. at this time. After each marking event, fish are allowed to recover in coolers of fresh water, at the appropriate temperature, before being returned to the general population.

The majority of juvenile chinook salmon in the program are transported from Eagle to Manchester for saltwater rearing during the time wild smolts are entering the Columbia River estuary. However, approximately 20% of the fish from each stock may remain in fresh water at Eagle to ensure representation in the event of a catastrophic loss at Manchester. Fish are transported between facilities in truck-mounted insulated tanks (typically 950 L capacity) with alarm and back-up oxygen systems on board. Loading volumes do not exceed 89 kg/m^3. All vehicles are equipped to provide the appropriate conditions (temperature, oxygen, capacity) to facilitate safe transport between locations. In addition, all vehicles have two-way radios and/or cellular telephones to provide routine or emergency communications. "Sentinel" groups of approximately 10 fish from each stock may be transported to Manchester approximately one week in advance of the general population to verify the physiological readiness of the fish to tolerate saltwater. Prior to offloading, transport water is tempered to within 2.0°C of the receiving water, and fish are moved, by stock, to 6.0 m circular tanks filled with full strength freshwater. Once in the circular tanks, full strength saltwater is allowed to flow into the tanks with mixing occurring over an approximate twelve-hour period, after which full strength saltwater is achieved (C. McAuley, NOAA Fisheries, Manchester Marine Experimental Station, personal communication).

Adult Transportation, Rearing, and Marking

Chinook salmon determined to be maturing are transported from Manchester to Eagle to complete the freshwater phase of their maturation and for spawning performance evaluation. Maturation state is determined by visual observation of secondary sex characteristics and by physical manipulation of the gonads through the body wall. Adults are transported using similar equipment and techniques as described above, and loading volumes do not exceed 89 kg/m^3. Maturing fish from multiple brood years are pooled by stock for transport to Eagle, although stocks that may pose a health risk to other program fish are transported in separate vehicles. Tanks are loaded with one-third strength saltwater to begin freshwater acclimation during transport. Once at Eagle, fish are immediately placed in 3.0 m circular tanks filled with full strength freshwater.

Cohorts with potentially maturing fish reared at Eagle are examined and any maturing fish are separated from the general population and taken off feed. Maturation sorts are initiated in August, and maturation is determined by visual observation of secondary sex characteristics and by manipulating the gonads through the body wall. Maturing fish are moved into 3.0 m circular tanks and pooled by stock with maturing fish received from Manchester.

All maturing adults from the WFYF are fitted with disc tags, and a small number also receive radio transmitters prior to their release for volitional spawning. Bi-color combinations on the tags identified fish to brood year and water temperature treatment (see below; Appendix A). Tri-color combinations on disc tags identified those fish that were identified as maturing in the second maturation sort at Manchester, which were held on ambient water at Eagle (Appendix A). Fish from brood year 1996 were also given tri-color tags (Appendix A) and were excluded from the temperature evaluation due to their small number and the potential confounding effect of their overall poor condition. Additionally, each disc tag has a unique number embossed on it to identify the individual. Water temperature in the anesthetic baths is determined by the temperature treatment the fish are being exposed to. Disc tags are attached to the fish by passing a stainless steel pin through a hole in the center of the tag and passing the pin through the musculature of the dorsal surface just ventral to the midline of the dorsal fin. A corresponding tag (same color code and number) is then slipped onto the pin on the opposite

side of the fish and secured by using needle-nose pliers to form a loop at the end of the pin. Finally, the pin is trimmed to minimize snagging on underwater debris after release. After receiving the disc tag but before being allowed to recover from the anesthetic, a radio transmitter (Advanced Telemetry Systems model 5 or 10-28) is gastrically implanted via the esophagus following Burger et al. (1985) in a subgroup of the fish released. The external antenna is crimped at a position corresponding to the corner of the fish's mouth and allowed to trail along the side of the body. The size of fish receiving radio transmitters were compared to the general population with a two-sample *t*-test to verify those receiving the additional tag were representative of the entire population. After marking, fish are allowed to recover in coolers of temperature appropriate fresh water before being returned to the holding tanks.

Chilled Water Experiments

A common thread linking previous releases of captive-reared chinook salmon is that these fish have consistently spawned several weeks later than their naturally produced counterparts (Hassemer et al. 1999, 2001; Venditti et al. 2002). In an attempt to address this shortcoming, additional water chilling capacity was added at Eagle in 2001 to assess if water temperature manipulations between the time maturing adults are returned to freshwater and release could be used to advance their spawn timing. While we could find no instances where this has been tested on chinook salmon, there is a substantial amount of literature describing the effect of temperature on the timing of ovulation in other salmonid species. Elevated holding temperature prior to spawning is shown to retard the onset of ovulation in rainbow trout *O. mykiss* (Pankhurst et al. 1996; Pankhurst and Thomas 1998; Davies and Bromage 2002), pink salmon *O. gorbuscha* (Beacham and Murray 1988), Atlantic salmon *Salmo salar* (Taranger and Hansen 1993), and Arctic char *Salvelinus alpinus* (Gillet 1991; Jobling et al. 1995). However, Henderson (1963) did not observe this relationship in eastern brook trout *S. fontinalis*.

Chinook salmon from the LEM and WFYF stocks determined to be maturing are separated into three groups for holding at two temperatures during their freshwater maturation at Eagle. Fish determined to be maturing during the first maturation sort at Eagle and Manchester are separated into control and test groups. Control fish are maintained on ambient well water (≈13.5°C), and test fish are held on chilled water (≈ 8.9°C). Care is taken to ensure that the entire range of fish size is represented in both groups. Mean group weights are calculated for each stock and brood year. Fish lighter than the group average are randomly assigned to either the test or control group and are classified as small. Those heavier than the group mean are also randomly divided between groups and designated as large. The size classification is maintained throughout the study to determine if water temperature has a differential effect on spawn timing relative to body size. A two-sample *t*-test is used to verify that no differences exist in overall fish size in both groups and to evaluate differences in size classifications. A Chi-square analysis is used to compare the spawn timing of chilled and ambient group females released to spawn volitionally. A third group of fish consisting of those determined to be maturing in a second maturation sort at Manchester (designated "late-arrivals") are held on ambient temperature water, but are not included in the temperature experiment due to the different amount of time they spent in fresh water compared to the experimental groups.

Monitoring Programs

Hatchery Spawning and Gamete Evaluation

Fish from the LEM stock remained at Eagle, were spawned in the hatchery, and the eggs remained on-site through the eyed stage of development. In addition to the date fish from each group become ripe, hatchery spawning allows us to compare a measure of egg quality (survival to the eyed stage) between the two temperature groups. This is important since elevated water temperature prior to ovulation is shown to reduce egg survival in salmonids (Pankhurst et al. 1996; Taranger and Hansen 1993; Gillet 1991). When one or more females is determined to be in spawning condition, milt is preharvested from males with the same treatment history and stored in plastic bags for up to approximately 2 h before use. Ripe females are stripped of their eggs and total fecundity is estimated by calculating the average egg weight from a subsample of approximately 50 eggs and dividing the total egg weight by the average egg weight. Eggs from each female are divided into one to three sublots of approximately equal size, fertilized with milt from a unique male, and placed in separate incubators (see Figure 3). The use of multiple males (from the same temperature treatment as the female) maximizes the genetic diversity in the hatchery crosses and acts as an aid in identifying which parent contributed nonviable gametes in cases of low (or no) fertilization. When the developing embryos have received approximately 325–350 CTUs, the eggs are shocked to identify and facilitate the removal of those that are dead or unfertilized. After shocking, incubators are checked daily and opaque eggs or those with fungal growth are removed. Survival to the eyed stage is calculated as the number of green eggs fertilized minus the number of dead or unfertilized eggs removed divided by the number of green eggs fertilized. Egg survival between test and control females is compared using a two-sample *t*-test. The eyed-eggs are then provided to biologists with the Shoshone-Bannock Tribe who place them in in-stream hatch-boxes within the LEM system.

Fish Health Monitoring

The captive rearing program utilizes disinfectants, antibiotics, vaccinations, and antifungal treatments to control pathogens. Dosage, purpose of use, and method of application for currently used drugs are as follows: 1) Antibiotic therapies: Erythromycin is administered orally, feeding medicated feed obtained from Bio-Oregon Inc. (Warrenton, Oregon) to produce a dose of 100 mg/kg of body-weight. Fish are fed medicated feed for up to a 28 day period to control BKD. When oral administration is not feasible as with anadromous adults, an intraperitoneal injection of erythromycin is given to fish at a dose of 20 mg/kg of body weight. Fingerlings are fed Oxytetracycline or oxolinic acid medicated feed at a dose of 75 mg/kg of body weight for 10 days to control outbreaks of pathogenic aeromonads, pseudomonads, and myxobacteria, bacteria, etc. as these cases arise. 2) Vaccinations: age-2 chinook salmon are vaccinated prior to shipment to saltwater with intraperitoneal injections of Vibrogen (Aqua Health, Ltd., Charlottetown, P.E.I., Canada) to control *Vibrio spp.* and Renogen (Aqua Health Ltd.) to control BKD. 3). Egg disinfection: newly fertilized eggs are water hardened in 100 mg/L solution of Iodophor for 30 minutes to inactivate viral and bacterial pathogens on the egg surface and in the perivitelline space.

Tissue samples are collected from carcasses during necropsies on program fish to monitor for the presence of common bacterial and viral pathogens. American Fisheries Society “Bluebook” procedures are employed to isolate bacterial or viral pathogens and to identify

parasite etiology. All examinations are conducted under the direction of the program fish pathologist. Genetic samples are also collected from carcasses in an effort to conduct mitochondrial DNA and/or nuclear DNA evaluations for chinook salmon populations held in the program.

Spawning adults are analyzed for common bacterial and viral pathogens such as BKD, infectious hematopoietic necrosis virus, and viral hemorrhagic septicemia. Tissue samples are collected from the kidney, spleen, and pyloric caeca of each fish, and ovarian fluid samples are collected from each female and analyzed at the Eagle Fish Health Laboratory. In addition, tissue from maturing chinook salmon transferred to the State of Idaho from Manchester are screened for *Piscirickettsia salmonis*, and additional ovarian fluid is "blind passed" in a separate test for the North American strain of viral hemorrhagic septicemia. These pathogens do not occur in Idaho but have recently been identified in fish reared at a seawater net pen location in close proximity to the Manchester site. Results of fish health analysis of spawners are used by IDFG and the CSCPTOC to determine disposition of eggs and subsequent juveniles.

Fish health is checked daily by observing feeding response, external condition, and behavior of fish in each tank as initial indicators of developing problems. In particular, fish culturists look for signs of lethargy, spiral swimming, side swimming, jumping, flashing, unusual respiratory activity, body surface abnormalities, and unusual coloration. Presence of any of these behaviors or conditions is immediately reported to the program fish pathologist. The presence of moribund fish is immediately reported to the fish pathologist for blood and parasite sampling. A fish pathologist routinely monitors carcasses from the captive rearing program to try to determine cause of death. When a treatable pathogen is either detected or suspected, the program fish pathologist prescribes appropriate prophylactic and therapeutic drugs to control the problem. Dead fish are routinely analyzed for common bacterial and viral pathogens (e.g., BKD, infectious hematopoietic necrosis virus, etc). Select carcasses may be appropriately preserved for pathology, genetic, and other analyses. After necropsy, carcasses that are not vital to further analysis are disposed of as per language contained in the ESA Section 10 permit for the program.

Growth and Survival of Brood Year 1996

Program year 2001 represented the end of contribution from brood year 1996 individuals. In order to track the contribution of this cohort through time growth, sources and magnitudes of mortality, and maturation rates were evaluated. Fish weights collected during routine sampling at both Eagle and Manchester were plotted over time, and both individual fish weight and group means are presented graphically. Major sources of mortality including disease, tagging, mechanical (e.g., equipment failure), maturation related, etc. were compiled. Mortality from Eagle and Manchester was combined into a single analysis. Finally, we determined the total number of brood year 1996 program fish from each study stream that reached sexual maturity and computed the percentage that matured at 2, 3, 4, and 5 years of age.

Volitional Spawning

Maturing chinook salmon are released to a 9.7 km section of the WFYF. The components of a blocking weir are flown to the site via helicopter and assembled at the downstream end of this section to ensure that program fish remain above. Trap boxes built into

the weir allow wild chinook salmon and other native species to pass in either direction. The study section is divided into six reaches approximately 1.6 km in length to permit systematic observations of chinook salmon spawning areas above the weir. No program control is imposed on the upstream movement of study fish, but habitat changes above the confluence of the WFYF and Cabin Creek make spawning above this point unlikely (personal observation). Finally, thermographs are deployed at the weir and near the upper extent of the study section to document the thermal histories of any redds spawned by captive-reared individuals and to determine when these redds should be sampled to determine fertilization rates and survival to the eyed-egg stage of development.

Maturing captive-reared chinook salmon are transported by truck from Eagle to a helipad near the U.S. Forest Service, Bonanza Guard Station (Challis National Forest) in preparation for release into the study section. At the helipad, fish are transferred to insulated coolers filled with water from the transport tank, and the coolers are secured inside specially constructed steel frames for transport under a helicopter during the approximately 2 km flight to the release site (Figure 4). Transport frames are secured to the helicopter with a 30.5 m synthetic cable, which is used to minimize the buildup of static electricity in the transport frames that could potentially harm the fish or ground personnel.

Figure 4. Equipment used to fly mature adult chinook salmon into the West Fork Yankee Fork Salmon river for volitional spawning.

Behavioral data collection begins approximately 24 h after fish are released. Observers are assigned two to four stream reaches each day, enabling the entire study section to be monitored over a two-day period. Observers walk slowly upstream watching for chinook salmon. When a fish is detected, the time is recorded and its habitat association and activity (Table 1) are observed and documented for 5 min. During this time, the observers use binoculars and polarized sunglasses to determine if it is a wild or a study fish based on the presence or absence of a disc tag. If it is a study fish the color combination of the tag is recorded, and if the number can be determined (or the fish is wild) its location is recorded on a global positioning

system (GPS) receiver. When multiple fish are observed simultaneously, activity, habitat, and location information are recorded separately for each individual.

Table 1. Habitat and behavior variables recorded during observations of captive-reared chinook salmon released into the West Fork Yankee Fork Salmon River for volitional spawning, August–October, 2001.

Habitat	**Definition**
Overhead vegetation	Associated with riparian vegetation overhanging the stream
Aquatic vegetation	Associated with aquatic vegetation
Cut bank	Under an overhanging bank
Open water (pool or run)	In a pool or run with no other structure
Open water (riffle tailout)	In a riffle or tailout with no other structure
Large woody debris	Within one body length of log(s)
General Behavior	**Definition**
Holding	Remaining in one position
Milling	Movement not resulting in displacement
Moving (A)	Movement in an upstream direction
Moving (B)	Movement in a downstream direction
Aggression	Aggression between chinook of undetermined sex
Spawn	Observed release of eggs and milt
Male Behavior	**Definition**
Courting (A)	Quiver
Courting (B)	Crossover
Aggression (A)	Male on male aggression
Aggression (B)	Male on female aggression
Aggression (C)	Male on other species aggression
Redd holding (A)	On or near a redd with female present
Redd holding (B)	On or near a redd with female absent
Satellite	Holding away or downstream of a courting pair
Female Behavior	**Definition**
Aggression (A)	Female on female aggression
Aggression (B)	Female on male aggression
Aggression (C)	Female on other species aggression
Redd holding (A)	On or near redd, no digging male present
Redd holding (B)	On or near redd, no digging male absent
Test dig	2 – 6 body flexures, not concentrated
Nest dig	5 – 8 body flexures in a concentrated area
Cover dig	8 – 12 body flexures along redd perimeter

When courting or digging activity is observed between chinook salmon during the first 5 min of observation, additional time is spent recording the frequency of these behaviors to estimate how close the pair is to spawning. If, based on these frequencies, the observer believes spawning could occur within 1-2 h, he remains with the pair and records their behaviors until 30 min after spawning. Behavioral observations are recorded in 10 min blocks at this point to facilitate comparisons of courting, aggression, and digging frequencies as spawning nears.

Radio-telemetry is also used to collect additional information on the movements, distribution, and fate of program individuals. This technique is used early in the season to estimate how far upstream study fish have traveled and allows us to concentrate observation effort in areas known to contain fish. Telemetry is also used to locate individuals associated with logjams and other dense cover that would otherwise not be visible to shoreline observers. Finally, radio-telemetry is used to locate carcasses to assist in determining the cause of mortality and whether or not the fish has spawned.

At the end of the study period, eyed-eggs are collected from redds spawned by captive-reared females to determine fertilization rates and survival to the eyed stage of egg development. Eyed-eggs are collected using the methods described above with the exception that sampling begins near the center of redds to minimize sampling time. Opaque eggs or those having fungal growth are considered dead and are preserved in 95% ethanol. Clear eggs are classified as viable and are placed in Stockard's solution, which causes developing embryos to become visible. Eggs in this category are further categorized as fertilized or blank depending on the presence or absence of an embryo. The number of eggs in each category is enumerated and the percentage in each computed. Finally, the number of eyed-eggs produced by captive-reared females is estimated from the proportion of fertilized eggs observed, estimated fecundity, and the total number of redds produced by program females.

RESULTS AND DISCUSSION

Brood Year Report

The following acronyms are used in the following section of the report to describe culture groups: NP refers to "natural parr" or fish collected from natal streams as wild parr; SN refers to "safety net" or fish generated from hatchery spawning events; and NE refers to "natural egg" or fish generated from the collection of eyed-eggs from redds constructed by wild adults.

Brood Year 1996

At the beginning of the reporting period, 12 LEM-NP and five WFYF-NP brood year 1996 chinook salmon were in culture at Eagle. Seven maturing LEM-NP were transferred to Eagle from Manchester on June 6, 2001 to complete their maturation in freshwater. On August 17, 2001, four maturing and one immature WFYF-NP fish were released to the WFYF. Six maturing LEM-NP females were used for hatchery spawning in 2001. At the end of the reporting period, zero brood year 1996 fish remained in culture at Eagle (Tables 2, 3).

Brood Year 1997

At the beginning of the reporting period, 17 LEM-NP and 13 WFYF-NP brood year 1997 chinook salmon were in culture at Eagle. Thirty (27 females/3 males) maturing LEM-NP and 37 (33 females/4 males) maturing WFYF-NP were transferred to Eagle from Manchester on June 6 and August 2, 2001 to complete their maturation in freshwater. On August 17, 2001, 42 maturing WFYF-NP fish were released into the WFYF for natural spawning and evaluation. Seventeen maturing LEM-NP (16 females/1 male) were used for hatchery spawning in 2001. At

the end of the reporting period, two WFYF-NP and zero LEM-NP fish remained in culture at Eagle (Tables 2, 3).

Brood Year 1998

At the beginning of the reporting period, 19 EFSR-SN and 23 EFSR-NP brood year 1998 chinook salmon were in culture at Eagle. Twenty-five (20 females/5 males) maturing LEM-NP, 35 (26 females/9 males) maturing WFYF-NP, 18 (10 females/8 males) maturing EFSR-NP, and nine (9 females/0 males) maturing EFSR-SN were transferred to Eagle from Manchester on May 27 and August 2, 2001 to complete their maturation in freshwater. On August 17, 2001, 44 maturing WFYF-NP were released into the WFYF for natural spawning and evaluation. Twenty-eight maturing LEM-NP (5 females/23 males) were used for hatchery spawning in 2001. At the end of the reporting period, two LEM-NP, zero WFYF-NP, two EFSR-NP and three EFSR-SN fish remained in culture at Eagle (Tables 2, 3, 4).

Brood Year 1999

At the beginning of the reporting period, 236 LEM-NE, 267 WFYF-SN, 138 EFSR-NE, and 75 EFSR-SN were in culture at Eagle. On April 30, 2001, 10 LEM-NE, 11 WFYF-SN, 11 EFSR-NE, and 10 EFSR-SN smolts were transferred to Manchester to be used as sentinel groups for rearing in saltwater. On May 4, 2001, 102 EFSR-NE and 231 WFYF-SN smolts were transferred to Manchester to complete rearing in saltwater. On May 9, 2001, 200 LEM-NE and 55 EFSR-SN smolts were transferred to Manchester to complete rearing in saltwater (Tables 2, 3, 4).

Brood Year 2000

At the beginning of the reporting period, 296 WFYF-NE, 497 EFSR-NE and 225 YFSR-NE were in culture at Eagle. At the end of the reporting period, 285 WFYF-NE, 463 EFSR-NE and 220 YFSR-NE pre-smolts were on station at Eagle (Tables 3, 4, 5).

Brood Year 2001

Eyed-egg collections in 2001 resulted in an initial inventory of 272 WFYF-NE and 311 EFSR-NE eyed-eggs. At the end of the reporting period, 266 WFYF-NE and 295 EFSR-NE developing fry were in culture (Tables 3, 4).

Eyed Egg Collection, Transport, and Incubation

Naturally spawned, eyed-eggs were collected from the EFSR and the WFYF to establish captive culture groups representing brood year 2001. Eggs were collected from six redds in the EFSR on September 18 and 26, 2001, and from six redds on the WFYF on September 19 and 27, 2001 (Table 6). Eyed-egg collections totaled 311 from the EFSR and 272 from the WFYF (Table 6). The eyed-eggs were transported to Eagle immediately after collection and were in incubators within 4–6 h of removal from the redds.

Eyed-eggs from both the EFSR and WFYF groups experienced excellent survival to hatch and initial ponding. The EFSR swim-up fry were ponded on November 21, 2001, with survival from collection to ponding of 96.8%. The WFYF fry were ponded on November 19, 2001 with survival from collection to ponding of 97.6%.

Eyed-eggs were also produced at Eagle when maturing program fish from the LEM were spawned to assess the effect of water temperature on gamete quality and maturation timing. A total of 25 females (14 Manchester- and 11 Eagle-reared) and 21 males (19 Manchester- and 2 Eagle-reared) were used in these crosses (Appendix B).

Once these eggs had reached the eyed stage of development, they were transferred from Eagle to the LEM drainage on October 18 and November 1, 2001. The eggs were provided to cooperators with the Shoshone-Bannock Tribe who placed them in in-stream incubators in Bear Valley Creek. Tribal cooperators received 2,372 eyed-eggs in the first shipment and 5,782 eyed-eggs in the second shipment. After distributing the eggs, Tribal biologists monitored the incubators to evaluate hatch rates, emergence rates, and dates for each.

Juvenile Rearing, Marking, and Transportation

Those fish representing brood year 2000 culture groups at Eagle were PIT tagged on two dates in 2001. A total of 239 juveniles from the EFSR, 294 from the WFYF, and 221 from the Yankee Fork Salmon River were tagged on June 22, 2001. An additional 239 juveniles from the EFSR were PIT tagged on June 25, 2001. The size of juveniles from the three systems were similar and averaged 102 mm FL, 11.6 g for fish from the EFSR, 101 mm FL, 11.4 g for those from the WFYF, and 100 mm FL, 11.0 g for those from the Yankee Fork Salmon River.

The majority of juvenile chinook salmon from brood year 1999 culture groups were transferred from Eagle to Manchester as smolts on three dates in 2001 for saltwater rearing. The first transfer took place on April 30 and included 10 fish from the EFSR-SN and LEM-NE groups and 11 fish from the EFSR-NE and WFYF-SN groups (Table 7). These fish acted as sentinels to test each group's ability to tolerate saltwater. Survival was high in all sentinel groups, and the remaining 102 EFSR-NE and 231 WFYF-SN smolts were transferred to Manchester on May 7, 2001 followed by 55 EFSR-SN and 200 LEM-NE smolts on May 10, 2001 (Table 7). After these transfers were completed, 10 fish from the EFSR-SN group and 25 from each of the other three groups remained on station at Eagle, and will be reared on freshwater until they are released or spawned in the hatchery.

Table 2. Summary of losses and magnitude of mortality for four Lemhi River captive chinook salmon culture groups reared at IDFG facilities in 2001.

	Culture Groups			
	BY96-NP	**BY97-NP**	**BY98-NP**	**BY99-NE**
Starting Inventory (January 1, 2001)	12[a]	17	25[a]	236[a]
Eyed-Egg to Fry				
Undetermined[b]	n/a	n/a	n/a	n/a
Mechanical Loss				
Handling	1	0	15	3
Jump-out	0	0	0	1
Transportation	0	1	0	0
Noninfectious				
Lymphosarcomo	0	0	0	0
Nephroblastoma	0	0	0	0
Other[c]	6	11	4	4
Infectious				
Bacterial	6	0	1	0
Viral	0	0	0	0
Other	0	0	0	0
Hatchery Spawning				
Male Spawners	0	1	23	0
Female Spawners	6	16	5	0
Cryopreservation	0	0	0	0
Maturation Study Fish	0	17	0	0
Relocation				
Transferred In	7	29	25	0
Transferred Out	0	0	0	210
Planted/Released	0	0	0	0
Ending Inventory (December 31, 2001)	0	0	2	18

[a] Starting inventory reflects an inventory adjustment made post-completion of the 2000 NMFS Annual Report.
[b] Typical egg to fry mortality includes non-hatching eggs, abnormal fry, and swim-up loss.
[c] Includes mortality due to maturation; culling associated with cultural anomalies; and all undetermined, noninfectious mortality.
[d] Includes mature females culled for physiological and morphological comparison study with captive chinook salmon.

Table 3. Summary of losses and magnitude of mortality for six West Fork Yankee Fork Salmon River captive chinook salmon culture groups reared at IDFG facilities in 2001.

	Culture Groups					
	BY96-SN	**BY97-NP**	**BY98-NP**	**BY99-SN**	**BY00-NE**	**BY01-NE**
Starting Inventory (January 1, 2001)	5	14[a]	23	267	296	272[b]
Eyed-Egg to Fry						
Undetermined[c]	n/a	n/a	n/a	n/a	n/a	4
Mechanical Loss						
Handling	0	2	3	3	3	0
Jump-out	0	0	0	0	0	0
Transportation	0	1	0	0	0	0
Noninfectious						
Lymphosarcoma	0	0	0	0	0	0
Nephroblastoma	0	0	0	0	0	0
Other[d]	0	4	12	1	6	2
Infectious						
Bacterial	0	0	0	0	2	0
Viral	0	0	0	0	0	0
Other	0	0	0	0	0	0
Hatchery Spawning						
Male Spawners	0	0	0	0	0	0
Female Spawners	0	0	0	0	0	0
Cryopreservation	0	0	0	0	0	0
Relocation						
Transferred In	0	37	36	0	0	0
Transferred Out	0	0	0	242	0	0
Planted/Released	5	42	44	0	0	0
Ending Inventory (December 31, 2001)	0	2	0	21	285	266

[a] Starting inventory reflects an inventory adjustment made post-completion of the 2000 NMFS Annual Report.
[b] Fall 2001 inventory.
[c] Typical egg to fry mortality includes non-hatching eggs, abnormal fry, and swim-up loss.
[d] Includes mortality due to maturation; culling associated with cultural anomalies; and all undetermined, noninfectious mortality.

Table 4. Summary of losses and magnitude of mortality for six East Fork Salmon River captive chinook salmon culture groups reared at IDFG facilities in 2001.

	Culture Groups					
	BY98-SN	**BY98-NP**	**BY99-SN**	**BY99-NE**	**BY00-NE**	**BY01-NE**
Starting Inventory (January 1, 2001)	19	23	75	138[a]	497	311[b]
Eyed-Egg to Fry						
Undetermined[c]	n/a	n/a	n/a	n/a	n/a	14
Mechanical Loss						
Handling	9	8	0	3	2	1
Jump-out	0	0	0	0	15	0
Transportation	0	0	0	0	0	0
Noninfectious						
Lymphosarcoma	0	0	0	0	0	0
Nephroblastoma	0	0	0	0	0	0
Other[d]	16	30	0	7	0	1
Infectious						
Bacterial	0	1	0	0	0	0
Viral	0	0	0	0	0	0
Other	0	0	0	0	17	0
Hatchery Spawning						
Male Spawners	0	0	0	0	0	0
Female Spawners	0	0	0	0	0	0
Cryopreservation	0	0	0	0	0	0
Relocation						
Transferred In	9	18	0	0	0	0
Transferred Out	0	0	65	113	0	0
Planted/Released	0	0	0	0	0	0
Ending Inventory (December 31, 2001)	3	2	10	15	463	295

[a] Starting inventory reflects an inventory adjustment made post-completion of the 2000 NMFS Annual Report.
[b] Fall 2001 inventory.
[c] Typical egg to fry mortality includes non-hatching eggs, abnormal fry, and swim-up loss.
[d] Includes mortality due to maturation; culling associated with cultural anomalies; and all undetermined, noninfectious mortality.

Table 5. Summary of losses and magnitude of mortality for one Main Yankee Fork Salmon River captive chinook salmon culture groups reared at IDFG facilities in 2001.

	Culture Groups
	BY00-NE
Starting Inventory (January 1, 2001)	225
Eyed-Egg to Fry	
Undetermined[a]	n/a
Mechanical Loss	
Handling	2
Jump-out	0
Transportation	0
Noninfectious	
Other[b]	3
Infectious	
Bacterial	0
Viral	0
Other	0
Hatchery Spawning	
Male Spawners	0
Female Spawners	0
Cryopreservation	0
Relocation	
Transferred In	0
Transferred Out	0
Planted/Released	0
Ending Inventory (December 31, 2001)	220

[a] Typical egg to fry mortality includes non-hatching eggs, abnormal fry, and swim-up loss.
[b] Includes mortality due to maturation; culling associated with cultural anomalies; and all undetermined, noninfectious mortality.

Table 6. Summary of eyed-egg collections in the East Fork Salmon River (EFSR) and the West Fork Yankee Fork Salmon River (WFYF) to establish brood-year 2001 culture groups at the Eagle Fish Hatchery. Eggs were collected from a total of six unique redds in each stream over two sampling dates.

Stream	Date	Redd 1	Redd 2	Redd 3	Redd 4	Redd 5	Redd 6	Total
EFSR	9/18/01	41	6	48	—	—	—	95
EFSR	9/26/01	—	—	—	71	50	95	216
Σ EFSR								311
WFYF	9/19/01	9	77	2	—	—	—	88
WFYF	9/27/01	—	—	—	73	70	41	184
Σ WFYF								272

Adult Transportation, Rearing, and Marking

Adult transport events included moving maturing fish from Manchester to Eagle for final freshwater maturation and then taking a portion of these fish to the WFYF where they were released for volitional spawning. Maturing fish (N = 161) were brought from Manchester to Eagle on four dates in 2001 (Table 7). Jacks (maturing males from brood year 1998) were generally brought to Eagle on May 8 and 11, 2001, while those maturing at age-4 and age-5 were transferred on June 6, 2001 (Table 7). A late maturation sort at Manchester identified those fish that were maturing but not detected previously, and these fish were brought to Eagle on August 2, 2001. Eighty-nine fish from the WFYF were held on fresh water at Eagle until August 17, 2001, when they were taken to their natal stream and released (Table 7).

Maturing study fish from the WFYF were disc tagged on August 2, 2001. A total of 89 fish were disc tagged in preparation for release and included four fish from brood year 1996 averaging 1,223 g (N = 3, range 739 g – 1,954 g), 42 fish from brood year 1997 averaging 2,650 g (N = 39, range 1,355 g – 3,801g), and 43 fish from 1998 that averaged 1,430 g (N = 36, range 513 g – 2,367 g). Nineteen fish from brood years 1997 and 1998 were also fitted with a radio transmitter in addition to a disc tag. Radio-tagged fish from brood years 1997 and 1998 averaged 2,768 g and 1,638 g, respectively and did not differ significantly from those that were disc tagged only (two-sample *t*-test; 1997 $P = 0.472$, 1998 $P = 0.114$; SYSTAT 2000).

Chilled Water Experiments

Maturing fish from the LEM and WFYF stocks were separated into treatment (chilled) and control (ambient) temperature tanks on June 15, 2001. Those from the LEM stock remained on the two temperature regimes until they were either removed for physiological sampling (Swanson et al. 2002) or spawned at Eagle. Those from the WFYF remained in the two temperature regimes until August 17, 2001 when they were released into that stream for volitional spawning. Water temperature in the chilled water tanks averaged 8.9°C (N = 6,726, SD = 0.61, range 8.3°C–14.1°C), while the ambient water tanks averaged 13.8°C (N = 6,770, SD = 0.30, range 13.3°C–14.7°C; Figure 5). A chiller failure on July 3, 2001 lasting 41 h 30 min allowed the test tank to reach the maximum temperature recorded, and a second failure lasting

2 h 30 min on August 9, 2001 allowed test tank temperatures to reach 11.5°C. Excluding these times from the dataset provides a more typical regime experienced by the chilled water groups (mean 8.8°C, range 8.3–9.6, SD = 0.28).

A third group of fish, determined to be maturing in the second sort at Manchester, were transferred to Eagle on August 2, 2001 and placed in ambient temperature tanks. This group consisted of five fish from brood year 1997 and nine from brood year 1998. One additional brood year 1997 Eagle-reared fish was also placed in this group when it was determined to be maturing.

Table 7. Summary of fish transfers conducted by the chinook salmon captive rearing program during 2001. LEM–Lemhi River, WFYF–West Fork Yankee Fork Salmon River, MAN–Manchester Marine Experimental Station, EAG–Eagle Fish Hatchery. NP, NE, and SN refer to natural parr, natural egg, and safety net groups, respectively.

Source Stream	Brood Year	EAG to MAN	Transfer Date	MAN to EAG	Transfer Date	EAG to WFYF	Transfer Date
LEM-NP	1996			7	Jun 6		
LEM-NP	1997			27	Jun 6		
LEM-NP	1997			3	Aug 2		
LEM-NP	1998			20	May 8		
LEM-NP	1998			5	Aug 2		
LEM-NP	1999	10	Apr 30				
LEM-NP	1999	200	May 10				
WFYF-NP	1996					4	Aug 17
WFYF-NP	1997			33	Jun 6	42	Aug 17
WFYF-NP	1997			4	Aug 2		
WFYF-NP	1998			26	May 11	43	Aug 17
WFYF-NP	1998			9	Aug 2		
WFYF-SN	1999	11	Apr 30				
WFYF-SN	1999	231	May 7				
EFSR-NP	1998			10	May 8		
EFSR-NP	1998			8	Aug 2		
EFSR-SN	1998			9	May 11		
EFSR-NE	1999	11	Apr 30				
EFSR-NE	1999	102	May 7				
EFSR-SN	1999	10	Apr 30				
EFSR-SN	1999	55	May 10				

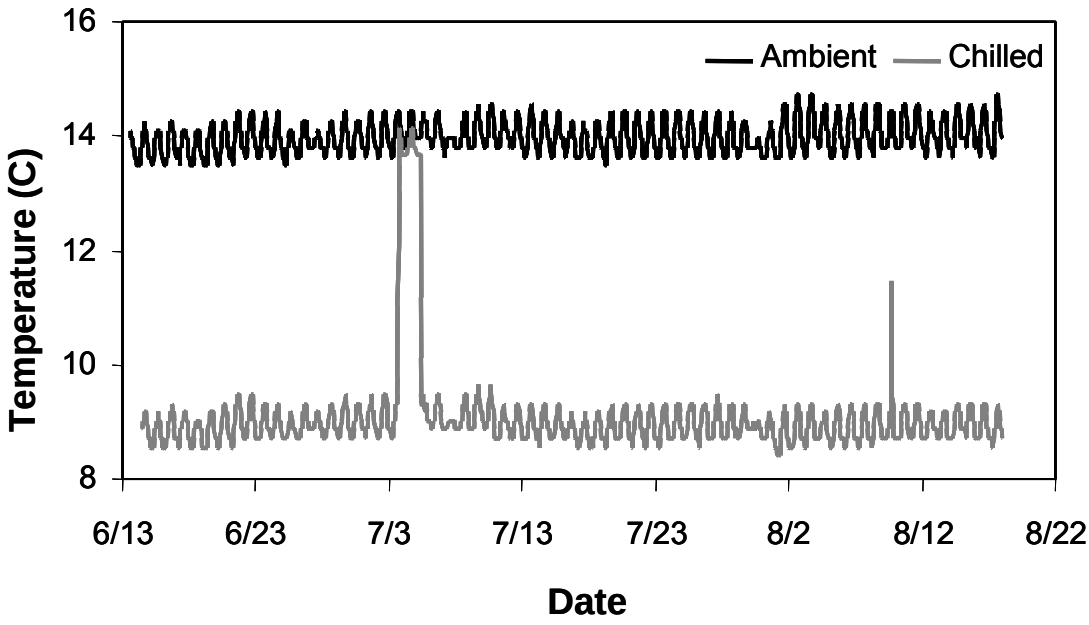

Figure 5. Chilled and ambient tank water temperatures experienced by maturing captive-reared chinook salmon at the Eagle Fish Hatchery during their final freshwater maturation, June–August, 2001.

Mean fish weight and size of maturing WFYF and LEM stock fish generally did not differ between treatment and control tanks, but groups classified as large were always significantly heavier than small groups. No significant differences (two-sample *t*-test; α = 0.05; SYSTAT 2000) in the overall mean weight of fish in the treatment and control groups were detected within stock and brood year (Table 8). Further analysis comparing the mean weight of fish in the two size classes between treatment and control groups also detected no significant difference in all but one case, where brood year 1997 WFYF treatment fish classified as small were heavier than their counterparts in the control group (Table 8). Conversely, significant differences in mean fish weight were detected in all comparisons between large and small size classes (Table 8).

Monitoring Programs

Hatchery Spawning and Gamete Evaluation

A total of 25 LEM females (11 treatment and 14 control) were spawned in 2001 (Appendix B), producing 21,500 green eggs. An additional control female was culled at spawning because of retained and polarized (over ripe) eggs. Overall egg survival to the eyed stage of development was 31.4% (range 0%-88%) for all fish combined. Mean egg survival to the eyed stage of development was 24.3% and 37.0% for treatment and control fish, respectively, and did not differ significantly (two-sample *t*-Test; *P* = 0.3484; SYSTAT 2000).

Table 8. Comparisons of mean weights of treatment and size groups of brood year (BY) 1997 and 1998 chinook salmon from the Lemhi River (LEM) and West Fork Yankee Fork Salmon River (WFYF) used to examine the effect of chilled water on maturation timing of fish at the Eagle Fish Hatchery and released to spawn volitionally in 2001. Fish were randomly assigned to control (C) or test (T) groups and held at 8.9°C and 13.8°C, respectively, and classified as large (L) or small (S) based on their size relative to overall group mean weights.

BY	Stock	Group	Size	N	Mean	SD	*P* value
1997	LEM	C		19	1961.1	651.1	0.951
1997	LEM	T		19	1974.4	685.2	
1998	LEM	C		10	1161.9	536.1	0.890
1998	LEM	T		13	1134.8	320.5	
1997	WFYF	C		18	2458.5	576.1	0.059
1997	WFYF	T		21	2814.8	563.8	
1998	WFYF	C		17	1458.5	456.2	0.725
1998	WFYF	T		19	1403.9	465.1	
1997	LEM		L	18	2407.6	633.1	0.000
1997	LEM		S	20	1571.8	373.5	
1998	LEM		L	10	1489.3	381.4	0.000
1998	LEM		S	13	883.0	190.8	
1997	WFYF		L	19	3066.7	494.6	0.000
1997	WFYF		S	20	2254.8	355.8	
1998	WFYF		L	18	1741.9	361.4	0.000
1998	WFYF		S	18	1117.6	299.2	
1997	LEM	C	L	9	2403.7	538.6	0.980
1997	LEM	T	L	9	2411.6	749.4	
1997	LEM	C	S	10	1562.7	466.6	0.917
1997	LEM	T	S	10	1580.9	276.7	
1998	LEM	C	L	4	1690.0	447.2	0.189
1998	LEM	T	L	6	1355.5	296.8	
1998	LEM	C	S	6	809.8	159.7	0.214
1998	LEM	T	S	7	945.7	203.9	
1997	WFYF	C	L	8	2905.5	438.1	0.236
1997	WFYF	T	L	11	3183.9	519.6	
1997	WFYF	C	S	10	2100.9	397.5	0.050
1997	WFYF	T	S	10	2408.7	238.0	
1998	WFYF	C	L	9	1798.6	292.5	0.580
1998	WFYF	T	L	9	1685.2	429.8	

Table 8, continued.

BY	Stock	Group	Size	N	Mean	SD	*P* value
1998	WFYF	C	S	8	1076.0	249.2	0.613
1998	WFYF	T	S	10	1150.8	343.6	
1997	LEM	C	L	9	2403.7	538.6	0.002
1997	LEM	C	S	10	1562.7	466.6	
1997	LEM	T	L	9	2411.6	749.4	0.004
1997	LEM	T	S	10	1580.9	276.7	
1998	LEM	C	L	4	1690.0	447.2	0.002
1998	LEM	C	S	6	809.8	159.7	
1998	LEM	T	L	6	1355.5	296.8	0.013
1998	LEM	T	S	7	945.7	203.9	
1997	WFYF	C	L	8	2905.5	438.1	0.001
1997	WFYF	C	S	10	2100.9	397.5	
1997	WFYF	T	L	11	3183.9	519.6	0.000
1997	WFYF	T	S	10	2408.7	238.0	
1998	WFYF	C	L	9	1798.6	292.5	0.000
1998	WFYF	C	S	8	1076.0	249.2	
1998	WFYF	T	L	9	1685.2	429.8	0.008
1998	WFYF	T	S	10	1150.8	343.6	

It appears that egg survival was primarily related to maternal factors. Individual females crossed with multiple males produced subfamilies with similar survival rates regardless of paternity. Individual males crossed with multiple females contributed to subfamilies whose survival varied widely and in relation to the overall survival rates for the individual females (Figure 6).

Egg survival to the eyed stage in 2001 was lower than previously observed in this program (Hassemer et al. 2001; Venditti et al. 2002). This decrease in gamete quality could have several possible explanations. First, a large portion of the females spawned in 2001 exhibited twisted and asynchronously developed ovaries, with deformity and reduced size generally occurring in the left ovary. The reduced egg survival may also have been attributable to the removal of a number of females from the spawning population for physiological and morphological comparisons with ocean-reared chinook salmon (results to be reported by NOAA Fisheries, Project 1993-05-600). Those fish sampled for this purpose had not matured to the point where sex could be determined visually or by physical manipulation, therefore size was used as a surrogate to help identify females. An unfortunate consequence to this was the “best” individuals based on physical appearance were removed from the population before they matured and were spawned.

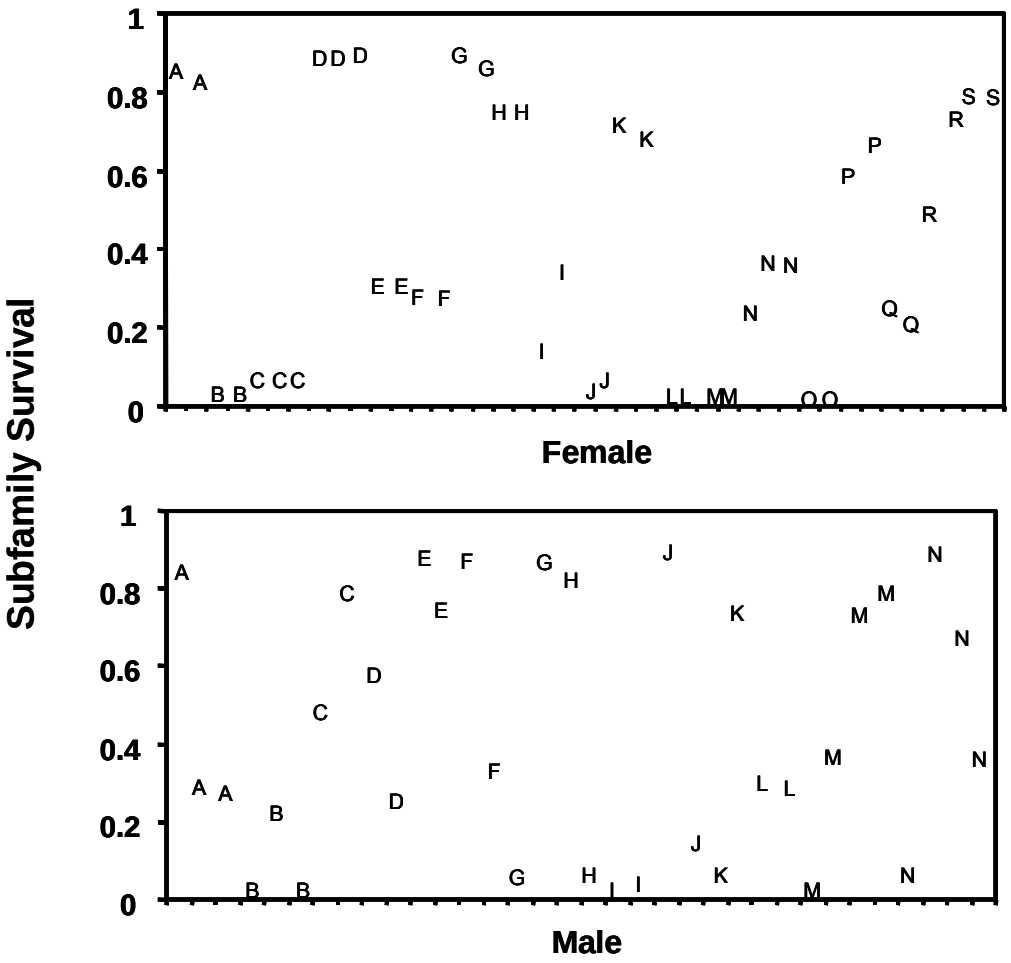

Figure 6. Ranges of proportional survival in subfamilies of eggs produced by individual females and fertilized by multiple males, and those produced by multiple females and fertilized by individual males (bottom graph). Subscripted letters attached to the female designations (A–S) correspond to the male used to fertilize that subfamily. Subscripted letters attached to the male designations (A–N) correspond to the female who produced that subfamily.

Fish Health Monitoring

In 2001, 149 laboratory accessions (representing 191 fish) were generated at the Eagle Fish Health Laboratory for captive chinook salmon. Cause of mortality and magnitude of loss for chinook salmon maintained at the Eagle Fish Hatchery during this reporting period are presented in Tables 2 through 5.

Monitoring for BKD in captive chinook salmon has been routinely conducted since the inception of the program in 1995. Of the 191 carcasses examined in 2001, six demonstrated clinical levels of this disease using the enzyme-linked immunosorbent assay. All BKD-related mortality (six cases) occurred in brood year 1996 chinook salmon from the LEM group collected

as natural parr. No BKD was identified in the safety-net rearing groups or those originating from the collection of eyed-eggs. During this reporting period, Erythromycin-medicated feed was administered twice as a prophylactic treatment (28 d periods).

In 2001, LEM chinook salmon juveniles were not found to be infested with the gill parasite *Salmincola* spp., indicating that the gastric intubation treatment with the parasiticide Ivermectin eliminated the parasite from the facility. In previous years, this infestation debilitated rearing groups of LEM chinook.

Naturally spawned chinook salmon juveniles collected from the LEM (and to a lesser extent, the WFYF) are infected with *Myxobolus cerebralis*, the causative agent of salmonid whirling disease. For LEM captive broodstocks, the prevalence of infection for 2001 was 26%. Mortality has not been attributed to the parasite, but occasional deformities have been observed.

Motile aeromonad septicemia, caused by *Aeromonas* and *Pseudomonas* spp., was detected in five broodstock groups and required antibiotic therapy. Treatments were effective in reducing loss.

Diagnostic assays for the salmonid rickettsial disease agent *Piscirickettsia salmonis* and the North American strain of viral hemorrhagic septicemia failed to demonstrate the presence of this diseases in brood fish that were returned from Manchester.

Growth and Survival of Brood Year 1996

Growth rate comparisons of brood year 1996 captive-reared chinook salmon indicated that those from Manchester attained a much larger size than those reared at Eagle. Sample weights collected from fish reared at Eagle in December 1998, June 1999, April 2000, and February 2001 show that program fish averaged 120 g, 336 g, 1049 g, and 1062 g in each sample, respectively (Figure 7). Sample weights collected from fish reared at Manchester at approximately the same times indicated that fish reared there were almost twice as large as those from Eagle. Groups of program fish at Manchester weighed during December 1998, July 1999, and June 2000 averaged 256 g, 752 g, and 2149 g, respectively (Figure 8). No size data are presented for these fish during 2001, because an insufficient number of brood year 1996 fish remained at Manchester after the 2000 adult release to provide meaningful data.

General sources of mortality were similar to those observed previously, but BKD was much more common in this group of fish than had been observed in earlier brood years (Hassemer et al 2001; Venditti et al. 2002). Clinical levels of BKD in this brood group were particularly devastating to program fish from the WFYF, where symptoms developed early and remained a significant source of mortality throughout the lifespan of this cohort. Other sources of mortality in this group included mechanical failure (when an inflow pipe clogged overnight), handling, parasitic infection, cold water disease, and maturation (Figure 9).

Brood year 1996 captive-reared chinook salmon from the WFYF matured at a much lower overall rate than previous cohorts, while maturation in LEM fish was similar to past groups from that stream. Mortality from BKD in WFYF fish was probably the major reason maturation was so low in this stock. Overall only 19 of 119 fish (16.0%) from the WFYF brought into the program matured, and of these 11 males (57.9%) matured at age two, three males (15.8%) matured at age three, one female (5.3%) matured at four years of age, and four females

(21.0%) matured at five years. Precocity was higher than observed in earlier cohorts from the WFYF (Hassemer et al. 2001; Venditti et al. 2002), but this may also be a result of the poor overall survival of this group due to BKD infection. In the LEM stock, 83 of 178 (46.6%) of brood year 1996 program fish matured. Precocial maturation in this group was 15.7% (13 fish); 18 (21.7%) matured as jacks, while 38 (45.8%) and 14 (16.9%) matured at four and five years of age, respectively. Although more fish from this group matured at ages four and five, the male contribution to these year-classes was extremely limited (four 4-yr olds and one 5-yr old).

Volitional Spawning

On August 17, 2001, a total of 89 adult chinook salmon from the captive rearing program were released into the WFYF. Releases were distributed over three locations containing several closely spaced pools. These areas were located approximately 300 m upstream of the weir (N = 42 fish) and at the upper and lower ends of a braided section of reach three (N = 21 and N = 26 fish, respectively). This was done to reduce densities at the release sites and to distribute fish throughout a portion of the study area.

Behavior and habitat usage observations began the day after release and continued for the duration of the study. Both the behaviors observed and the habitats used were consistent with increasing maturation and propensity to spawn. Early in the observation period, few spawning-related activities were observed. Most fish were seen holding position or less commonly moving in a directed manner (Figure 10), presumably to locate potential spawning areas, find suitable holding areas, or distribute themselves throughout the habitat. Habitat associations during this time mirrored these behaviors, with captive-reared chinook salmon being most commonly observed in pools, near large woody debris, or in run type habitats (Figure 11). The importance of deep pools for holding by prespawn salmonids has been described for chinook salmon (Briggs 1953; Torgersen et al. 1999), Atlantic salmon (Bardonnet and Baglinière 2000), and steelhead (Nakamoto 1994). Torgersen et al. (1999) and Bardonnet and Baglinière (2000) also observed the importance of structure to prespawn salmonids, which in the WFYF is mainly provided by large woody debris. As the season progressed and the fish began to mature, activities associated with redd construction and maintenance or aggression began to dominate the behaviors observed in the captive-reared chinook salmon (Figure 10). At the same time, most fish moved out of the pools and took up residence over spawning gravel in tail-outs. However, fish in pools continued to make up >10% of the observations through the end of the study period and probably represented resting areas for spawning fish, or females that did not mature, or males that were unable to compete for spawning access.

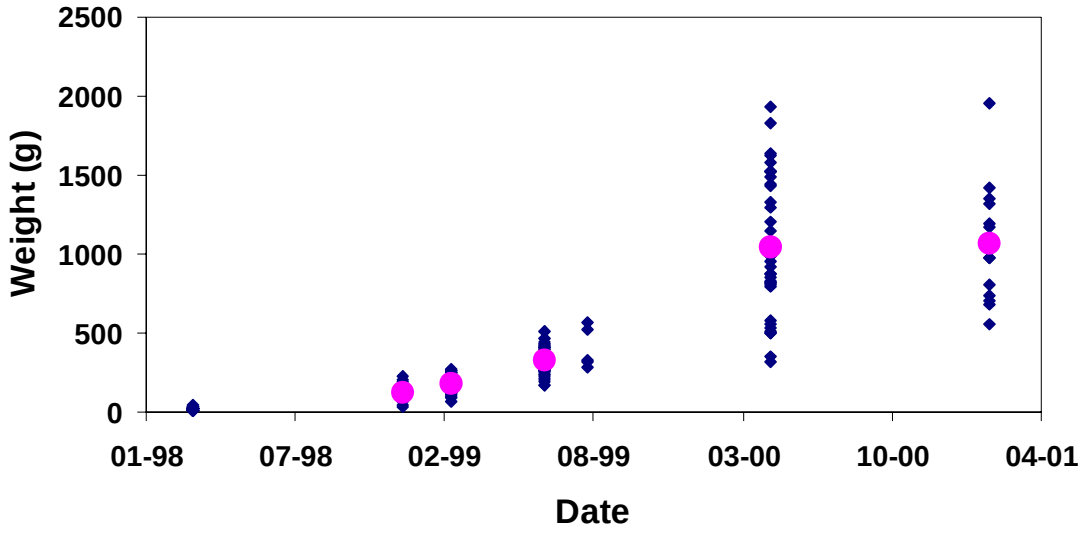

Figure 7. Growth of brood year 1996 chinook salmon reared in freshwater at Eagle Fish Hatchery. Circles represent group average weight.

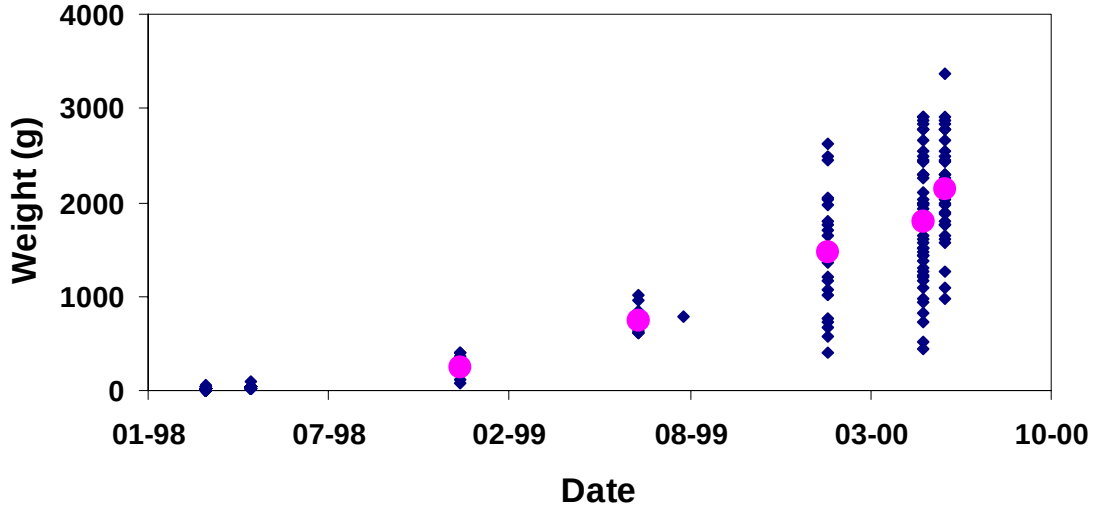

Figure 8. Growth rates for brood year 1996 chinook salmon reared at Manchester Marine Experimental Station. Circles represent group average weight.

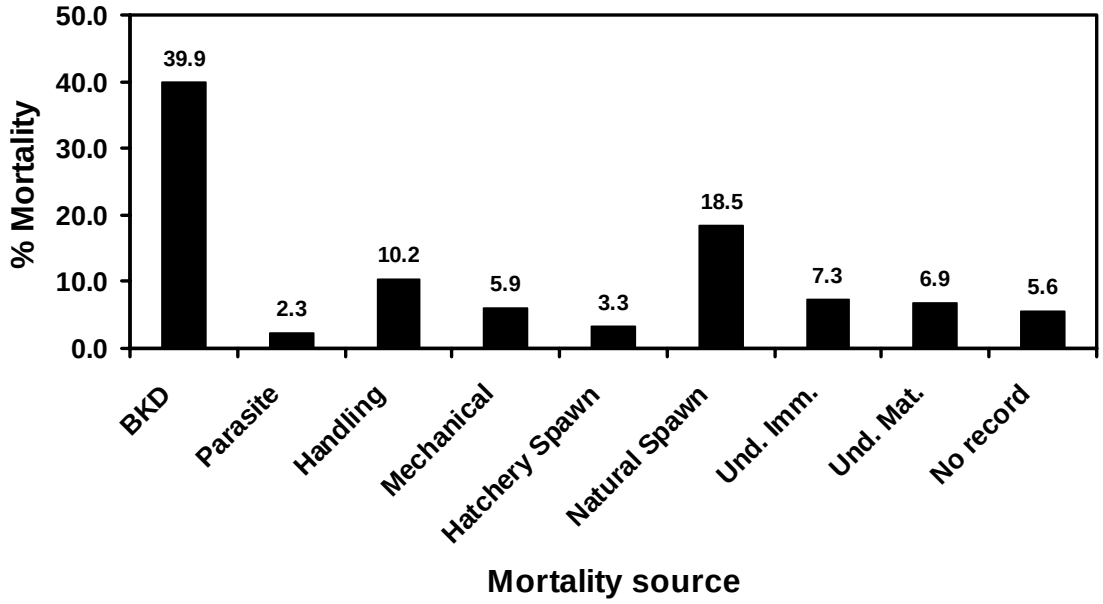

Figure 9. Sources of mortality in brood year 1996 captive-reared chinook salmon. Abbreviations include BKD = bacterial kidney disease and Und. = fish that died of undetermined causes.

Eighteen female chinook salmon from the captive rearing program constructed redds and presumably spawned in the WFYF in the summer of 2001. We estimated 41 of the fish released in 2001 were female, which represents a 43.9% spawning rate. However, this percentage underestimates the actual spawner percentage, as not all females survived to spawn. The estimate of female number is based on genetic sex assays from four-year-old fish (brood year 1997; provided by NOAA Fisheries Northwest Fisheries Science Center) and the assumption that all five-year-olds (brood year 1996) were female and all three-year-olds (brood year 1998) were male. The first redd initiated by a study female was observed on August 30, 2001, and additional redds were initiated fairly regularly through September 17, 2001 (Table 9). Females from the ambient group constructed nine redds, while those from the chilled group built six and the late arrivals constructed three (Table 9).

We observed and documented eight unique spawning events involving captive-reared females: three with wild males and five with captive-reared males. Our observations indicated captive-reared males displayed the same courtship behaviors as wild males, but the frequency of behaviors differed between the two groups relative to the time until spawning (Figure 12). The frequency of quivers and crossovers by wild males generally increased as spawning approached with a pronounced spike immediately prior to spawning (Figure 12). Courtship frequencies by captive-reared males remained constant or declined slightly during the period leading up to spawning, although the spike immediately prior to spawning was observed (Figure 12). The largest difference between the two groups of males was that captive-reared males were much less aggressive toward other chinook salmon or resident fish than were wild males (Figure 12).

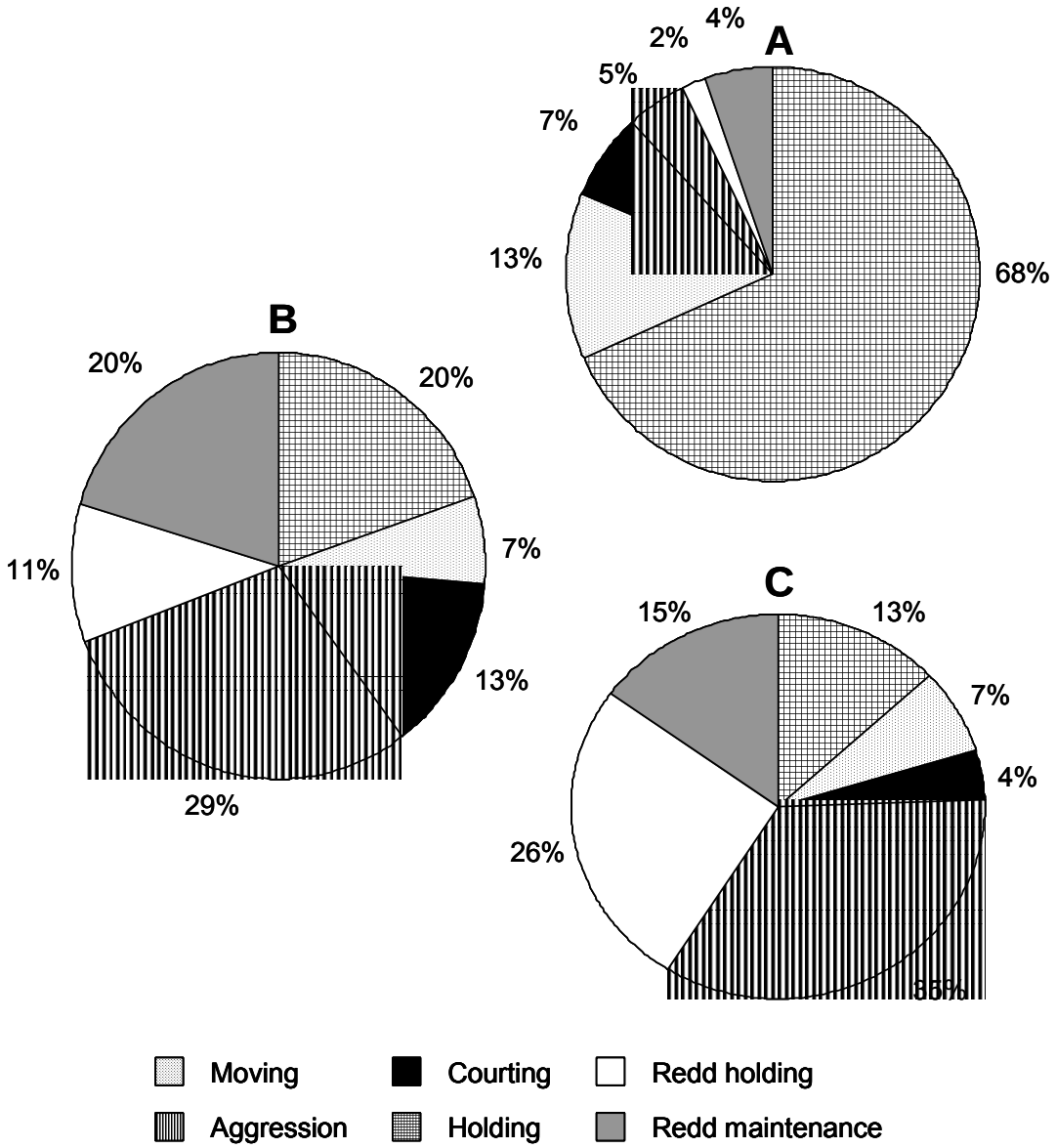

Figure 10. General behaviors of captive-reared chinook salmon released into the West Fork Yankee Fork Salmon River in the summer of 2001. Data were collected during standardized 5 min observation intervals. The charts represent information from the following time periods A: August 19–September 1, B: September 2–September 15, and C: September 16–September 23.

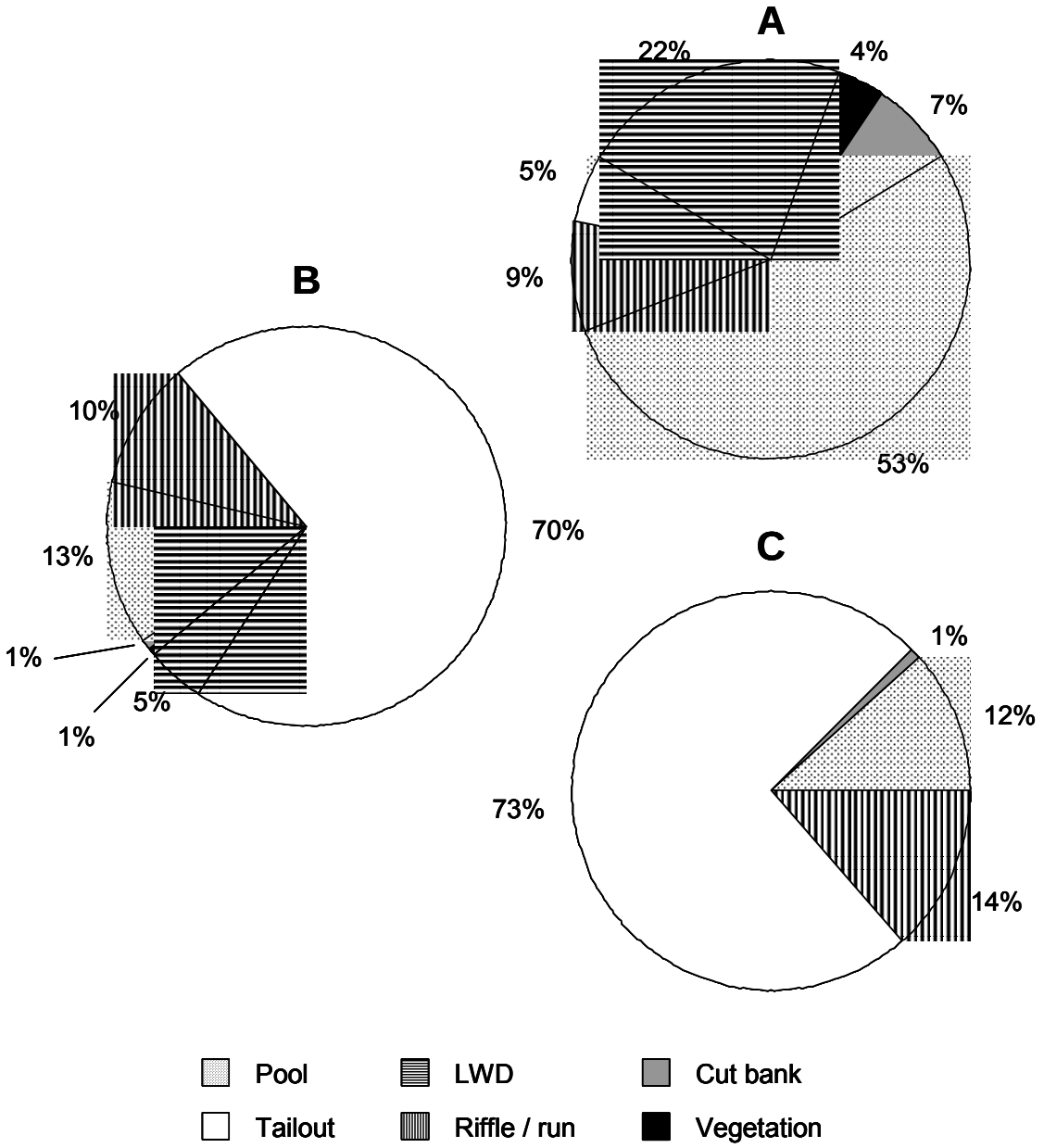

Figure 11. Habitat associations of captive-reared chinook salmon released into the West Fork Yankee Fork Salmon River in the summer of 2001. Data were collected during standardized 5 min observation intervals. The charts represent information from the following time periods, A: August 19–September 1, B: September 2–September 15, and C: September 16–September 23.

Table 9. Date of first redd initiation by captive-reared chinook salmon in the West Fork Yankee Fork Salmon River, August–September 2001. Control fish were held on ambient well water (~13.8°C) at the Eagle Fish Hatchery during final freshwater maturation, while treatment fish were held on chilled water (~8.9°C). Late arrivals were fish identified as maturing during a second sort and not transferred to the Eagle Fish Hatchery in time to be included in the temperature experiment.

Date	Female
8/30/01	Control
8/31/01	Late Arrival
9/1/01	Treatment
9/1/01	Treatment
9/2/01	Treatment
9/2/01	Control
9/4/01	Control
9/5/01	Treatment
9/5/01	Treatment
9/7/01	Control
9/8/01	Late Arrival
9/9/01	Control
9/9/01	Control
9/10/01	Control
9/13/01	Late Arrival
9/14/01	Control
9/17/01	Treatment
9/17/01	Control

Peak courting frequencies observed in captive-reared males were similar to those observed in ocean-reared hatchery chinook salmon that spawned in experimental channels (Berejikian et al. 2000). However, these fish displayed a pattern of increasing courtship frequency similar to that of the wild males in this study. Reduced frequencies of courtship and aggression have also been observed in comparisons of farmed and wild chinook (Chebanov and Riddell 1998) and Atlantic salmon allowed to spawn naturally (Fleming et al. 1996).

Captive-reared females displayed digging patterns similar to those reported in the literature. Study females made approximately 2-3 nest digs during each 10 min observation period until egg deposition. After deposition females proceeded to cover dig almost continuously for about 10 min and maintained elevated digging frequencies for at least 30 min (Figure 13). This general behavior pattern has been reported in chinook (Berejikian et al. 2000) and coho salmon (O. *kisutch*; Berejikian et al. 2001) and is probably common to all stream spawning salmonids.

The effects of chilled water on spawn timing in chinook salmon remain unclear, but results to date suggest this is a strategy worth pursuing, potentially with the addition of concurrent photoperiod manipulations. Field observations of spawning dates for the two groups of females in the WFYF did not differ ($\chi^2_{(0.05,\,1)}$ = 2.667, $P \approx 0.10$), although the expected frequencies used in the Chi-square test were not generally considered large enough to produce reliable estimates (Moore and McCabe 1989). However, it is important to note that all treatment females except one initiated spawning by September 5, 2001, while control females continued to initiate spawning until September 17, 2001 (Table 9). In LEM fish, the use of chilled water

produced no discernable effect on when females matured, but this experiment was hampered by having most of the "quality" females (based on size and appearance) sacrificed for physiological comparisons with anadromous returnees. Males from the treatment group did initiate spermiation approximately 10–14 d earlier than those in the control group.

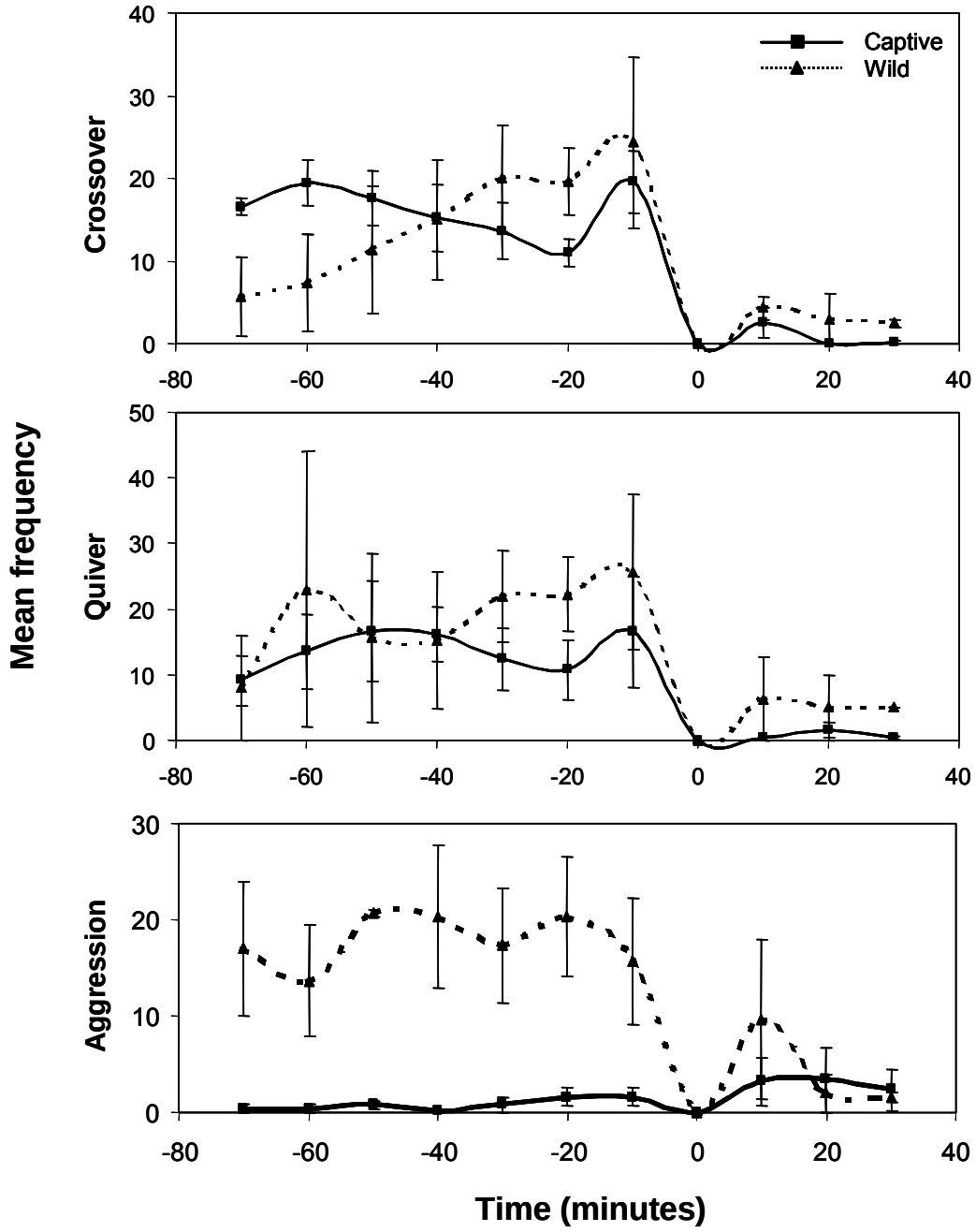

Figure 12. Mean (±S.E.) frequencies of courtship and aggression in male captive-reared and wild chinook salmon observed spawning with captive-reared females in the West Fork Yankee Fork Salmon River, August–October 2001. Time zero is spawning; negative and positive numbers are minutes prior and post spawning, respectively.

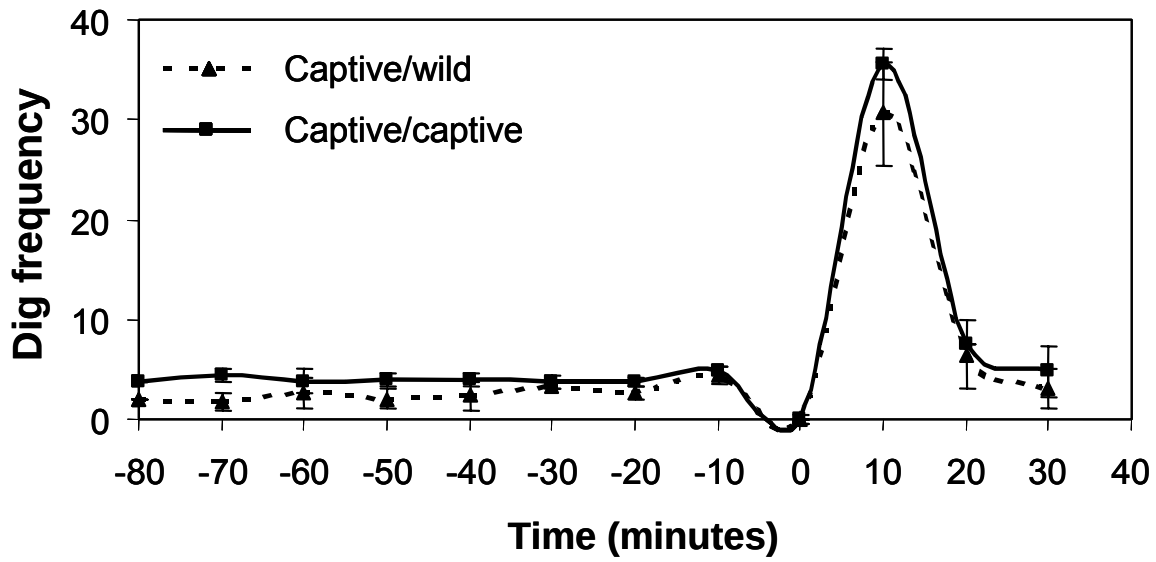

Figure 13. Mean (±S.E.) frequencies of digging by captive-reared, female chinook salmon observed spawning with captive-reared (solid line) and wild males (dashed line) in the West Fork Yankee Fork Salmon River, August–October 2001. Time zero is spawning; negative and positive numbers are minutes prior and post spawning, respectively.

Field Gamete Evaluation

Eyed-eggs were collected from a portion of the redds spawned by captive-reared chinook salmon females on October 15 and 16, 2001 to estimate egg fertilization rate and survival to the eyed stage of development. Based on accumulated thermal exposure, we estimated that eggs in seven of 18 redds spawned by study fish had progressed to the eyed stage of development (by the above dates) and were suitable for sampling. One additional redd spawned by a captive-reared female was sampled after receiving approximately 250 CTUs. The fertilization rate of viable eggs in this redd was determined based on the property of Stockard's solution to cause developing embryos to become visible before eye pigmentation develops. Eggs were collected from five of the eight redds sampled. The percentage of viable eggs in these redds ranged from 0%-89% (Table 10). All of the eggs determined to be viable at the time of collection were fertilized (as determined by the presence of a visible embryo).

One redd, constructed by a treatment female, contained no viable eggs, although it appeared to have been constructed in high quality habitat and was well developed. Sampling in this redd revealed that it was constructed on a thin (approximately 7 cm) layer of gravel/cobble armoring over a large, decayed log. Once the probe was worked through the armoring, only wood chips and dead (opaque) eggs were lifted out of the substrate. The buried woody debris was apparently quite large, as sampling at several locations within and around the redd yielded only wood chips below the armoring layer.

We used information obtained by sampling captive-spawned redds and from hatchery spawning activities to estimate the total number of eyed-eggs produced by captive-reared

chinook salmon in the WFYF in 2001. Our fecundity estimate was based on values obtained from captive-reared LEM females sampled for physiological comparisons with anadromous returnees and spawning at Eagle in 2001 and averaged 1,221 eggs/female. Egg survival to the eyed stage of development averaged 68.3% (omitting the redd built on the submerged log), and all viable eggs examined were fertilized (Table 10). Applying the following formula to these data provides an estimate of 15,010 eyed eggs produced by program fish:

Eyed-eggs = Number of redds X Mean fecundity X Proportion viable eggs X Proportion fertilized.

Table 10. Results from sampling redds spawned by captive-reared females in the WFYF. Treatment and control fish refer to those held on chilled and ambient temperature water, respectively, at the Eagle Fish Hatchery during final maturation. Eggs were collected October 15-16, 2001.

Redd	Viable Eggs	Dead Eggs	% Viable	% Viable Fertilized	Female	Male
1	16	2	88.9	100	Control	Wild
2	9	22	29.0	100	Control	Treatment
3	25	10	71.4	100	Treatment	Wild
4	21	4	84.0	100	Control	Wild
5	0	35	0		Treatment	Unknown

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APPENDICES

Appendix A. Summary of weight, brood year (BY), rearing location (EAG = Eagle Fish Hatchery, MAN = Manchester Marine Experimental Station) and tags used to identify captive-reared chinook salmon released into the West Fork Yankee Fork Salmon River (WFYF) for volitional spawning and Lemhi River fish spawned at Eagle to assess the effect of water temperature on maturation timing. Disc tag colors included B–blue, W–white, Y–yellow, and O–orange. Experimental fish making up the control group (C) were held on ambient temperature water during final maturation at Eagle, while the treatment group (T) was exposed to chilled water. Fish in the two groups were further differentiated as large (L) or small (S) depending on whether they were heavier or lighter than the mean weight for their brood year, respectively.

PIT Tag Code	BY	Stock	Weight (g)	Size Group	Treatment Group	Rearing Location	Disc Color	Disc Number	Radio Frequency
223F3D325D	1996	WFYF				EAG	B/W/B	58	
2240581F06	1996	WFYF	977			EAG	B/W/B	77	
2240790327	1996	WFYF	1954			EAG	B/W/B	97	
22407A545E	1996	WFYF	739			EAG	B/W/B	75	
515C270C18	1997	WFYF	2330	L	C	EAG	O/W	143	
516025334A	1997	WFYF	2341	L	C	EAG	O/W	101	
515F58397D	1997	WFYF	1593	S	C	EAG	O/W	107	
515B401771	1997	WFYF	3325	L	C	MAN	O/W	149	151.043
515B446363	1997	WFYF	2799	L	C	MAN	O/W	139	
515B4C3210	1997	WFYF	3525	L	C	MAN	O/W	123	150.581
515B7F7F1E	1997	WFYF	2735	L	C	MAN	O/W	111	
515C2B0E77	1997	WFYF	3159	L	C	MAN	O/W	145	
515D3C4A63	1997	WFYF	2772	L	C	MAN	O/W	115	150.802
5160302057	1997	WFYF	3057	L	C	MAN	O/W	137	
515B4D5F01	1997	WFYF	2372	S	C	MAN	O/W	140	150.390
515B565418	1997	WFYF	1934	S	C	MAN	O/W	135	150.080
515C256C05	1997	WFYF	2129	S	C	MAN	O/W	141	
515C642758	1997	WFYF	2550	S	C	MAN	O/W	129	
515D464B6A	1997	WFYF	1355	S	C	MAN	O/W	131	
515F61451D	1997	WFYF	2053	S	C	MAN	O/W	103	
5160293840	1997	WFYF	2080	S	C	MAN	O/W	117	
5160355F00	1997	WFYF	2357	S	C	MAN	O/W	105	
51603C5626	1997	WFYF	2586	S	C	MAN	O/W	125	
515F597910	1997	WFYF	1525		LA	MAN	W/B/O	106	
515F641B6A	1997	WFYF	1552		LA	MAN	W/B/O	124	
51600C5A01	1997	WFYF	1174		LA	MAN	W/B/O	106	
51602E0230	1997	WFYF	820		LA	MAN	W/B/O	122	
51603A385F	1997	WFYF			LA	MAN	W/B/O	146	
515B6F5420	1997	WFYF	2253	L	T	EAG	B/W	88	
515F556264	1997	WFYF	3801	L	T	EAG	B/W	78	
51603C512B	1997	WFYF	2500	L	T	EAG	B/W	51	
5160323E26	1997	WFYF	2190	S	T	EAG	B/W	54	
515B3F1660	1997	WFYF	3007	L	T	MAN	B/W	57	151.533
515B4D735E	1997	WFYF	2708	L	T	MAN	B/W	96	
515C024A40	1997	WFYF	3433	L	T	MAN	B/W	52	151.313
515C2D5469	1997	WFYF	3277	L	T	MAN	B/W	64	
516027574D	1997	WFYF	3104	L	T	MAN	B/W	56	
51602C3E76	1997	WFYF	3714	L	T	MAN	B/W	76	
516032073E	1997	WFYF	3636	L	T	MAN	B/W	70	
515B4C081F	1997	WFYF	2581	S	T	MAN	B/W	71	151.253
515B514E6B	1997	WFYF	2608	S	T	MAN	B/W	72	151.412
515B5A581F	1997	WFYF	2573	S	T	MAN	B/W	87	
515C367B69	1997	WFYF	2131	S	T	MAN	B/W	84	
515D343E2A	1997	WFYF	2124	S	T	MAN	B/W	82	150.513
5160295A0E	1997	WFYF	2096	S	T	MAN	B/W	79	

Appendix A, continued.

PIT Tag Code	BY	Stock	Weight (g)	Size Group	Treatment Group	Rearing Location	Disc Color	Disc Number	Radio Frequency
51603C723F	1997	WFYF	2640	S	T	MAN	B/W	62	
3D9.1BF0EC33BF	1998	WFYF	1381	L	C	EAG	B/O	195	
3D9.1BF0ED1908	1998	WFYF	1495	L	C	EAG	B/O	174	
3D9.1BF0EC45B3	1998	WFYF	905	S	C	EAG	B/O	179	
3D9.1BF0ECD37C	1998	WFYF	708	S	C	EAG	B/O	159	
3D9.1BF0EC313B	1998	WFYF	1685	L	C	MAN	B/O	185	
3D9.1BF0EC3F89	1998	WFYF	2352	L	C	MAN	B/O	175	150.260
3D9.1BF0EC55BA	1998	WFYF	2050	L	C	MAN	B/O	183	
3D9.1BF0ECEC3D	1998	WFYF	1944	L	C	MAN	B/O	163	
3D9.1BF0ED3F6C	1998	WFYF	1679	L	C	MAN	B/O	197	151.563
3D9.1BF0ED4BA6	1998	WFYF	1812	L	C	MAN	B/O	151	
3D9.1BF0EE6FD4	1998	WFYF	1789	L	C	MAN	B/O	169	
3D9.1BF0DF4945	1998	WFYF	1137	S	C	MAN	B/O	155	151.604
3D9.1BF0E0E008	1998	WFYF	872	S	C	MAN	B/O	173	151.644
3D9.1BF0EC4114	1998	WFYF	979	S	C	MAN	B/O	171	
3D9.1BF0ED461F	1998	WFYF	1428	S	C	MAN	B/O	193	
3D9.1BF0ED4C6A	1998	WFYF	1300	S	C	MAN	B/O	167	
3D9.1BF0EC3C1C	1998	WFYF	1519		LA	MAN	W/Y/B	13	
3D9.1BF0EC3F02	1998	WFYF	1150		LA	MAN	W/Y/B	19	
3D9.1BF0EC431E	1998	WFYF	1580		LA	MAN	W/Y/B	33	
3D9.1BF0EC5C42	1998	WFYF	1279		LA	MAN	W/Y/B	37	
3D9.1BF0ECDAFE	1998	WFYF	990		LA	MAN	W/Y/B	39	
3D9.1BF0ED3798	1998	WFYF	1564		LA	MAN	W/Y/B	11	
3D9.1BF0ED3C16	1998	WFYF	950		LA	MAN	W/Y/B	29	
3D9.1BF0ED4E5F	1998	WFYF	1064		LA	MAN	W/Y/B	25	
3D9.1BF0EDB083	1998	WFYF	1167		LA	MAN	W/Y/B	23	
3D9.1BF0EC55AE	1998	WFYF	1011	L	T	EAG	Y/W	38	
3D9.1BF0ED1E06	1998	WFYF	1049	L	T	EAG	Y/W	28	
3D9.1BF0EC414A	1998	WFYF	755	S	T	EAG	Y/W	02	
3D9.1BF0EC5EC8	1998	WFYF	921	S	T	EAG	Y/W	24	
3D9.1BF0ED4E84	1998	WFYF	513	S	T	EAG	Y/W	34	
3D9.1BF0EC2DEA	1998	WFYF	1682	L	T	MAN	Y/W	42	151.394
3D9.1BF0EC3EC0	1998	WFYF	2367	L	T	MAN	Y/W	26	150.884
3D9.1BF0EC46AE	1998	WFYF	1780	L	T	MAN	Y/W	20	151.895
3D9.1BF0ECE747	1998	WFYF	1821	L	T	MAN	Y/W	40	
3D9.1BF0ED2940	1998	WFYF	1912	L	T	MAN	Y/W	30	
3D9.1BF0ED3FD7	1998	WFYF	1945	L	T	MAN	Y/W	44	
3D9.1BF0EE3D42	1998	WFYF	1600	L	T	MAN	Y/W	04	
3D9.1BF0DEFDF4	1998	WFYF	1572	S	T	MAN	Y/W	14	151.725
3D9.1BF0DFF436	1998	WFYF	1302	S	T	MAN	Y/W	46	151.975
3D9.1BF0EC2DCA	1998	WFYF	1107	S	T	MAN	Y/W	22	
3D9.1BF0EC4EBE	1998	WFYF	1104	S	T	MAN	Y/W	50	
3D9.1BF0ED4A37	1998	WFYF	1362	S	T	MAN	Y/W	32	
3D9.1BF0EE3036	1998	WFYF	1305	S	T	MAN	Y/W	12	
515B457630	1997	Lemhi	1187	S	T	MAN			
515B476C5B	1997	Lemhi	1695	S	T	MAN			
515B476E6F	1997	Lemhi	2455	L	T	MAN			
515B4E0424	1997	Lemhi	2109	S	T	MAN			
515B566772	1997	Lemhi	3014	L	T	MAN			
515B567847	1997	Lemhi	1662	S	T	MAN			
515B596057	1997	Lemhi	1530	S	T	MAN			
515B5B6F7B	1997	Lemhi	1750	S	T	MAN			
515B73700E	1997	Lemhi	3244	L	T	MAN			
5160255027	1997	Lemhi	1460	S	T	MAN			
51602D4E66	1997	Lemhi	3271	L	T	MAN			
5160325C68	1997	Lemhi	1792	S	T	MAN			
5160332B75	1997	Lemhi	3059	L	T	MAN			
515B470C21	1997	Lemhi	1882	S	C	MAN			
515B48567C	1997	Lemhi	2063	S	C	MAN			

Appendix A, continued.

PIT Tag Code	BY	Stock	Weight (g)	Size Group	Treatment Group	Rearing Location	Disc Color	Disc Number	Radio Frequency
515B537403	1997	Lemhi	1829	S	C	MAN			
515B55612F	1997	Lemhi	2974	L	C	MAN			
515B576B3A	1997	Lemhi	2493	L	C	MAN			
515B5A7C06	1997	Lemhi	2149	S	C	MAN			
515B770E6E	1997	Lemhi	1757	S	C	MAN			
515D3F1768	1997	Lemhi	2973	L	C	MAN			
515F514348	1997	Lemhi	1421	S	C	MAN			
516027566E	1997	Lemhi	1632	S	C	MAN			
51602B376C	1997	Lemhi	2263	L	C	MAN			
51602F552E	1997	Lemhi	2769	L	C	MAN			
51603A2F2C	1997	Lemhi	2852	L	C	MAN			
51603B0B21	1997	Lemhi	1109	S	C	MAN			
515B4E457E	1997	Lemhi	1851	L	T	EAG			
515B571B3E	1997	Lemhi	1617	L	T	EAG			
51603B2C2F	1997	Lemhi	1560	L	T	EAG			
515D425744	1997	Lemhi	1329	S	T	EAG			
51603C0B5E	1997	Lemhi	1295	S	T	EAG			
515D446F14	1997	Lemhi	1633	L	T	EAG			
515B556238	1997	Lemhi	1868	L	C	EAG			
51600F383C	1997	Lemhi	1931	L	C	EAG			
515F4D1556	1997	Lemhi	780	S	C	EAG			
515B7E5458	1997	Lemhi	1005	S	C	EAG			
515B49111C	1997	Lemhi	1510	L	C	EAG			
5158580039	1997	Lemhi	1143		LA	MAN			
515B4F021E	1997	Lemhi	1740		LA	MAN			
51602C7F2C	1997	Lemhi	519		LA	MAN			
3D9.1BF0DF3A0F	1998	Lemhi	1082	S	T	MAN			
3D9.1BF0DF4800	1998	Lemhi	1334	L	T	MAN			
3D9.1BF0DF8867	1998	Lemhi	1140	S	T	MAN			
3D9.1BF0DFE217	1998	Lemhi	1628	L	T	MAN			
3D9.1BF0DFF609	1998	Lemhi	1305	L	T	MAN			
3D9.1BF0E005C2	1998	Lemhi	906	S	T	MAN			
3D9.1BF0E008D9	1998	Lemhi	938	S	T	MAN			
3D9.1BF0E009C0	1998	Lemhi	1489	L	T	MAN			
3D9.1BF0E01403	1998	Lemhi	927	S	T	MAN			
3D9.1BF0E01525	1998	Lemhi	1569	L	T	MAN			
3D9.1BF0E01A85	1998	Lemhi	1093	S	T	MAN			
3D9.1BF0DF3D40	1998	Lemhi	921	S	C	MAN			
3D9.1BF0DFE034	1998	Lemhi	1446	L	C	MAN			
3D9.1BF0DFE74A	1998	Lemhi	2343	L	C	MAN			
3D9.1BF0DFF0E5	1998	Lemhi	1014	S	C	MAN			
3D9.1BF0E0023B	1998	Lemhi	1609	L	C	MAN			
3D9.1BF0E006D1	1998	Lemhi	703	S	C	MAN			
3D9.1BF0E01222	1998	Lemhi	771	S	C	MAN			
3D9.1BF0E01436	1998	Lemhi	1362	L	C	MAN			
3D9.1BF0E019AA	1998	Lemhi	877	S	C	MAN			
3D9.1BF0E0008E	1998	Lemhi	534	S	T	EAG			
3D9.1BF0DF48B4	1998	Lemhi	808	L	T	EAG			
3D9.1BF0DFDE72	1998	Lemhi	573	S	C	EAG			

Appendix B. Summary of hatchery crosses at the Eagle Fish Hatchery in 2001. All fish were of Lemhi River origin from brood years (BY) 1996–1998 and part of an experiment to assess the effect of water temperature on maturation timing. Mean survival for each female is the proportion of eggs surviving to the eyed stage and is computed using the geometric mean of the proportion survival in each subfamily.

Spawn Date	Female Origin	Female BY	Temperature Group	Female Weight (g)	Total Fecundity	Male Origin	Male BY	Green Eggs	Eyed Eggs	Mean Survival
9/14/2001	NMFS	BY97	Chilled	1188	1177	NMFS	BY98	523	443	0.833
						NMFS	BY98	504	413	
9/14/2001	NMFS	BY97	Chilled	1145	909	NMFS	BY98	310	5	0.016
						NMFS	BY98	299	5	
9/14/2001	NMFS	BY97	Ambient	835					Not	Spawned
9/14/2001	NMFS	BY96	Ambient	1048	1431	NMFS	BY98	480	26	0.057
						NMFS	BY98	478	28	
						Lost	Tag	473	28	
9/17/2001	NMFS	BY96	Ambient	1400	1819	NMFS	BY98	540	471	0.880
						NMFS	BY98	540	474	
						Lost	Tag	539	479	
9/21/2001	NMFS	BY97	Chilled	1041	984	NMFS	BY98	406	122	0.296
						NMFS	BY98	368	107	
9/24/2001	NMFS	BY98	Chilled	817	1244	NMFS	BY98	358	103	0.281
						NMFS	BY98	336	92	
9/24/2001	NMFS	BY97	Ambient	1096	1379	NMFS	BY98	529	472	0.880
						NMFS	BY98	520	451	
9/24/2001	NMFS	BY97	Ambient	820	805	NMFS	BY98	293	218	0.740
						NMFS	BY98	277	204	
9/26/2001	EAGLE	BY97	Ambient	671	1035	NMFS	BY98	235	2	0.009
9/26/2001	NMFS	BY98	Ambient	1373	2064	NMFS	BY98	250	36	0.217
						NMFS	BY98	214	70	
9/26/2001	NMFS	BY97	Chilled	1224	1495	NMFS	BY98	666	26	0.049
						NMFS	BY98	659	40	
9/26/2001	NMFS	BY97	Chilled	1403	1370	NMFS	BY98	520	0	0.000
10/1/2001	NMFS	BY97	Ambient	1281	825	NMFS	BY98	407	283	0.683
						Lost	Tag	388	260	
10/1/2001	EAGLE	BY96	Ambient	98	1186	NMFS	BY98	525	0	0.000
						EAGLE	BY97	511	0	
10/1/2001	EAGLE	BY96	Ambient	1030	1357	NMFS	BY98	653	0	0.000
						NMFS	BY97	654	0	
10/1/2001	EAGLE	BY96	Ambient	1001	665	NMFS	BY98	335	0	0.000
10/1/2001	NMFS	BY96	Ambient	1266	1856	NMFS	BY98	611	134	0.306
						NMFS	BY98	630	230	
						Lost	Tag	590	211	
10/4/2001	EAGLE	BY97	Ambient	732	864	NMFS	BY98	326	0	0.000
						NMFS	BY98	308	0	
10/4/2001	EAGLE	BY97	Chilled	1427	1786	NMFS	BY98	636	367	0.618
						NMFS	BY98	650	430	
10/4/2001	EAGLE	BY97	Chilled	1135	1033	NMFS	BY98	396	99	0.229
						NMFS	BY98	387	81	
10/4/2001	EAGLE	BY98	Chilled	1150	877	NMFS	BY98	127	0	0.000
10/10/2001	EAGLE	BY98	Ambient	811	1183	EAGLE	BY98	525	256	0.598
						NMFS	BY98	508	372	
10/10/2001	EAGLE	BY97	Ambient	1400	1401	EAGLE	BY98	664	522	0.787
						NMFS	BY98	662	521	
10/10/2001	EAGLE	BY97	Chilled	1346	1527	NMFS	BY98	527	20	0.038
10/10/2001	NMFS	BY97	Chilled	895	263	NMFS	BY98	163	53	0.325

Prepared by:

David A. Venditti
Senior Fisheries Research Biologist

Catherine Willard
Fisheries Research Biologist

Trisha Giambra
Fisheries Technician

Dan Baker
Fish Hatchery Manager

Paul Kline
Principal Fisheries Research Biologist

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

_____
Virgil K. Moore, Chief
Bureau of Fisheries

_____
Steve Yundt
Fisheries Research Manager