REDFISH LAKE SOCKEYE SALMON
CAPTIVE BROODSTOCK PROGRAMS

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INTRODUCTION

In December 1991, the National Marine Fisheries Service (NMFS) listed Snake River sockeye salmon (*Oncorhynchus nerka*) as endangered under the U.S. Endangered Species Act (ESA). This action was the result of a petition presented to NMFS by the Shoshone-Bannock Tribe of Idaho. The petition requested NMFS to consider the status of these fish under the ESA. Subsequently, NMFS conducted a formal Biological Status Review for these fish. After considering the precipitous decline of this population, from a healthy status in the 1950s to few fish returning in the late 1980s, as well as the ecological significance and biological integrity of the species, the NMFS Biological Review team concluded in favor of listing (Waples et al. 1991).

NMFS is developing a formal Recovery Plan for Snake River sockeye salmon. In cooperation with the Idaho Department of Fish and Game (IDFG), the Bonneville Power Administration (BPA), and others, NMFS has begun interim recovery measures for anadromous Snake River sockeye salmon. These efforts focus on protecting the last known remnants of this stock: sockeye salmon that return to Redfish Lake in the Sawtooth Basin of Idaho at the headwaters of the Salmon River. Because of the critically low population size of Redfish Lake sockeye salmon, interim recovery measures are centered around a series of captive broodstocks to maintain the species while habitat improvements are underway (Flagg 1993, Johnson 1993).

There are several known forms of *O. nerka*. The anadromous sockeye salmon usually spends 1 to 2 years in its nursery lake before migrating to sea as a smolt. Anadromous sockeye salmon remain at sea for 2 to 3 years before returning to the natal area to spawn (Foerster 1968, Groot and Margolis 1991). Two other *O. nerka* forms remain in fresh water to mature and reproduce. Residual sockeye salmon are progeny of anadromous fish and produce mostly anadromous offspring (Ricker 1938, Foerster 1968, Groot and Margolis 1991). The more distinct kokanee form appears to have diverged from anadromous stock in recent geological time and is fully adapted to fresh water (Foerster 1968, Groot and Margolis 1991). Residual sockeye salmon in Redfish Lake were included in the anadromous gene pool for ESA protection, while kokanee were excluded.

Since both anadromous and residual forms of sockeye salmon inhabit Redfish Lake along with kokanee, a continuing challenge has been to differentiate them from the kokanee in developing broodstocks. Fortunately, there are a number of mechanisms to help differentiate sockeye salmon from kokanee. First, there is both spatial and temporal separation of the two *O. nerka* forms in Redfish Lake. The anadromous and residual forms are beach spawners that spawn in the lake in late October, whereas the kokanee spawn in a tributary to the lake in early September. Also, kokanee skin and flesh may be more red at spawning than sockeye salmon maintained on the same diet (Waples 1992). This is because kokanee, which live in a carotenoid-poor environment, appear to be more efficient than sockeye salmon at utilizing carotenoid in the diet. In addition, recent investigations have indicated that anadromous and residual sockeye salmon can be differentiated from kokanee by both protein electrophoresis[1] and DNA analysis (Brannon et al. 1992). Recent information also suggests that since anadromous fish spend time in seawater, an environment rich in strontium, it is possible to distinguish the progeny of anadromous parents based on the elevated strontium/calcium ratio in the primordial core of their otoliths (Kalish 1990). All of the criteria described above are being used in helping differentiate kokanee from anadromous sockeye salmon.

This paper describes the current status of Redfish Lake sockeye salmon captive broodstock recovery programs.

STATUS OF CAPTIVE BROODSTOCKS

Between 1991 and 1993, a number of captive broodstocks have been initiated to preserve the Redfish Lake sockeye salmon. Sources for these broodstocks include: 1) juveniles captured during their outmigration from Redfish Lake; 2) adults captured returning to Redfish Lake; and 3) mature residuals captured in the lake. Most past attempts to rear sockeye salmon to maturity in seawater have ended in failure due to high mortality from disease and poor gamete quality of captive-reared spawners[2,3].

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[1] Robin Waples. National Marine Fisheries Service. Northwest Fisheries Science Center. Seattle, Washington. Pers. commun. October 1993.

[2] Chris Wood. Department of Fish and Oceans. Pacific Biological Station. Nanaimo, B.C., Canada. Pers. commun. 1991.

However, culture in pathogen-free fresh water has generally resulted in higher survival to spawning and higher percentages of viable gametes[2,3]. One of our primary obligations when maintaining an endangered species in protective culture is ensuring the highest possible survival. Therefore, full-term freshwater rearing was chosen for these endangered species captive broodstocks.

In most cases, fish in the captive broodstocks will be grown to maturity, spawned, and their progeny released into Redfish Lake. Enhancement strategies include growing the juveniles in a hatchery or in net-pens in Redfish Lake for presmolt release to the lake in the fall. These juveniles would overwinter in the lake and outmigrate naturally as yearling smolts the next spring. Other juveniles may be reared in the hatchery for release into Redfish Lake as yearling smolts in the spring. In addition, a few maturing adults from Idaho captive broodstocks may be released in the fall to spawn naturally in Redfish Lake.

Outmigrant-based captive broodstocks

Juvenile *O. nerka* were captured by IDFG in a smolt trap as they exited Redfish Lake during the spring in 1991, 1992, and 1993. Presumably, these fish are progeny of the single pair of anadromous adults observed in the lake in 1989 mixed with residuals and resident kokanee.

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[3] William Waknitz. NMFS, Manchester Marine Experimental Station. Manchester, Washington. Pers. commun. 1991.

In spring 1991, *O. nerka* outmigrants were collected in the smolt trap and moved to the IDFG Eagle Hatchery near Boise, Idaho. It is estimated that another 4,000 outmigrants passed downstream in 1991. About 50% of the 759 outmigrants captured in 1991 have survived 2.5 years, from the time of capture to fall 1993. Some mortality during rearing was attributable to bacterial kidney disease (BKD) and aeromonad infection. Although these were mostly yearling fish at capture (1989 brood), and were expected to mature in 1993 as Age-4 fish, very few (about 15%) appear to be maturing in 1993. Only twenty-four maturing adults (12 males and 12 females) from this broodstock were released into Redfish Lake in late August to spawn naturally. These fish were sonic tagged and are being tracked to identify their spawning locations. It is projected that another 15 to 20 females will spawn in captivity this year, resulting in 30,000 to 40,000 eggs. Over 250 immature fish will be held at Eagle Hatchery to be spawned during the next 2 years.

In spring 1992, 79 *O. nerka* outmigrants were collected in the smolt trap and moved to the IDFG Eagle Hatchery. It is estimated that another 1,200 fish outmigrated in 1992. Survival of these fish during the 1.5 years from capture to fall 1993 has been about 88%. We expect most of these fish to spawn between fall 1994 and 1996.

In spring 1993, 35 *O. nerka* outmigrants were collected in the smolt trap and moved to the IDFG Eagle Hatchery. It is estimated that another 600 fish outmigrated in 1993. Survival of these fish during the 6 months from capture to fall 1993 has been almost 100%, and most of these fish should spawn between fall 1995 and 1997.

We are most interested in breeding the portion of these captive broodstock populations that originated from anadromous parents. A combination of factors described above (e.g., age and time of maturity, Sr/Ca ratios, skin and flesh color, genetics, etc.) will be used to help separate sockeye salmon from kokanee. Only gametes from fish of confirmed anadromous parentage will be used in recovery programs.

Residual captive broodstocks

Members of the NMFS Biological Status Review team theorized that residuals helped maintain the Redfish Lake sockeye salmon population during historic population lows (Waples et al. 1991). In fall 1992, a number of residuals were observed spawning on the Sockeye Salmon Spawning Beach in Redfish Lake and some of them were captured. Thirty-five eggs were recovered from a "spawned-out" female and were fertilized with milt from a residual male that was also captured. Survival of these fish during the year, from capture to fall 1993, has been almost 100%. We anticipate that most of these fish will spawn between fall 1996 and 1998.

IDFG is undertaking efforts to capture more residuals in fall 1993. To date, eight male and two female residuals have been captured. These fish will be spawned in November 1993.

Anadromous captive broodstocks

The most valuable of the captive broodstocks are derived from adult sockeye salmon returning to Redfish Lake. We are confident that these fish are part of the anadromous sockeye salmon gene pool from Redfish Lake. Progeny of returning adult sockeye salmon have the highest likelihood (of the available broodstocks) of aiding the recovery of the species in Redfish Lake.

In 1991, three males and one female adult sockeye salmon returned to Redfish Lake and were captured and held by IDFG. The female spawned volitionally with an unknown combination of males, on gravel placed in the holding tank. This spawning resulted in deposition of about one-half of the female's eggs (about 1,000 eggs). The female was then removed from the tank and the remaining eggs strip spawned. About four-fifths of the stripped eggs were separated into three lots to be fertilized with milt from individual males. The remainder were fertilized with pooled milt from all three males. Two geographically separate captive-brood populations were established from these egg lots in order to reduce the risk of catastrophic loss due to mechanical failure, human error, or disease.

Approximately one-half the progeny of adults that returned to Redfish Lake in 1991 were transferred to NMFS Northwest Fisheries Science Center in Seattle, Washington. Survival of these fish has been about 72% during 1.75 years of rearing (from hatch in January 1992 to fall 1993), with most mortalities due to

BKD. The remaining 1991-brood Redfish Lake sockeye salmon are in the custody of IDFG and are being held at Eagle Hatchery. Survival of the fish at IDFG has been over 90% during 1.75 years of rearing. We anticipate that most of these fish (at both NMFS and IDFG) will mature during the fall of 1995 and 1996 as normal Age-4 and Age-5 fish.

In fall 1992, a single male sockeye salmon returned to Redfish Lake, and its milt was cryopreserved for mating with future generations.

In fall 1993, two female and six male sockeye salmon returned to Redfish Lake. These fish were held by IDFG at the Sawtooth Hatchery and strip spawned in October 1993, producing over 6,000 eggs. A full-factorial mating design resulted in six half-sib groups from each female. In addition, a portion of each female's eggs were crossed with cryopreserved milt from the single male sockeye salmon that returned to Redfish Lake in 1992. It is anticipated that NMFS and IDFG will subdivide each of these 14 mating crosses for captive-broodstock rearing.

DISCUSSION

The use of captive-broodstock technology holds promise as a means of accelerating recovery of depleted stocks. One of the current barriers to restoration of many depleted stocks of salmonids in the Columbia River Basin and elsewhere is the availability of suitable numbers of juveniles for supplementation. The relatively high fecundity of Pacific salmon, coupled with potentially high survival in protective culture, allows captive broodstocks to produce large numbers of juveniles in a single generation. We believe that maintenance of each year-class of broodstock in captivity for only a single generation or a limited number of generations should help assure that genetic integrity and adaptability to native habitats are preserved.

Captive broodstocks should be viewed as a short-term measure to aid in recovery, never as a substitute for returning naturally spawning fish to the ecosystem. The first juvenile sockeye salmon from our captive broodstocks will be released into Redfish Lake in 1994. Other research is underway in Redfish Lake to determine the carrying capacity and the feasibility of lake fertilization as enhancement strategy (Spaulding 1993).

The relatively stable egg supply provided by the captive broodstock program should help guarantee the success of recovery efforts for Redfish Lake sockeye salmon. It is a virtual certainty that, given the critically low population size, without the captive broodstock programs, Redfish Lake sockeye salmon would soon be extinct.

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