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Status Review for Snake River Sockeye Salmon

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SUMMARY

To be considered for protection under the U.S. Endangered Species Act (ESA), a group of organisms must qualify as a "species" as defined by the ESA. The NMFS Species Definition Paper (Waples 1991) provides a framework for evaluating the petition for Snake River sockeye salmon (*Oncorhynchus nerka*) in this context. However, a lack of key information precludes a definitive determination at critical points of the decision process. This is particularly true for the first key question that must be addressed, Are Snake River sockeye salmon and kokanee distinct gene pools? This question is inherently tied to the question, Are post-Sunbeam Dam sockeye salmon in Redfish Lake direct descendants of the original (pre-1900) sockeye salmon gene pool, or have they recently been produced by the kokanee gene pool? The Biological Review Team unanimously agreed that there is insufficient information at present to determine with any reasonable degree of certainty the origin of the current sockeye salmon gene pool. After some discussion, the team reached a strong consensus that, in this instance, our obligation as stewards of the resource requires us to proceed under the assumption that recent sockeye salmon in Redfish Lake are descended from the original sockeye salmon gene pool. Therefore, as stipulated in the Species Definition Paper, the anadromous (sockeye salmon) component of *O. nerka* was considered separately from the nonanadromous (kokanee) component in determining whether an ESA listing is warranted.

Available information indicates that Snake River sockeye salmon meet both of the criteria necessary to be considered a "species" under the ESA: They are reproductively isolated from other sockeye salmon populations, and they represent an important component in the evolutionary legacy of the biological species. Given the extremely low numbers in the remaining population, the threshold question is not really an issue. Therefore, the decision to treat Redfish Lake sockeye salmon as

distinct from kokanee leads to a recommendation by the NMFS Biological Review Team to list the "species" as endangered. Although no adult sockeye salmon were observed in Redfish Lake in 1990, a declaration of extinction would be premature because other year classes may return through at least 1993. Research opportunities for 1991 may provide information pertinent to this petition. If further research indicates that Redfish Lake sockeye salmon and kokanee are not reproductively isolated (and therefore should be considered as a unit for ESA purposes), additional information will need to be developed to determine whether the combined unit is a "species" and, if so, whether it is threatened or endangered.

ACKNOWLEDGMENTS

The status review for Snake River sockeye salmon was conducted by the NMFS Northwest Region Biological Review Team (BRT). The extensive public record developed pursuant to this petition and discussions of that record by the ESA Technical Committee formed the basis for the review. Members of the BRT for sockeye salmon were: David Damkaer, Thomas Flagg, Elizabeth Garr, Orlay Johnson, Robert Jones, Conrad Mahnken, Gene Matthews, Gerald Monan, Michael Schiewe, Merritt Tuttle, Robin Waples, John Williams, and Gary Winans.

INTRODUCTION

Sockeye salmon (*Oncorhynchus nerka*) are native to the Snake River and historically were abundant in several lake systems in Idaho and Oregon. In this century, a variety of factors (including overfishing, irrigation diversions, obstacles to migrating fish, and eradication through poisoning) have led to the demise of all Snake River sockeye salmon except those returning to Redfish Lake in the Stanley Basin of Idaho. Following recent declines in that population as well, the Shoshone-Bannock tribe of Idaho petitioned the National Marine Fisheries Service (NMFS) to list Snake River sockeye salmon as an endangered "species" under the U.S. Endangered Species Act (ESA). To determine whether such an action was warranted, NMFS formed a Biological Review Team to review the status of Snake River sockeye salmon. This document reports the results of that status review and summarizes recommendations of the Biological Review Team regarding the ESA petition.

THE QUESTION OF EXTINCTION

It has been suggested that a full status review of Snake River sockeye salmon is not appropriate because the population is functionally extinct. The fact that no adult sockeye salmon were observed in Redfish Lake in 1990 lends support to this view. However, there is no provision in the ESA for declaring a "species" extinct until the last individual perishes. Redds (nests) of adult sockeye salmon were observed in Redfish Lake in 1988 and 1989 (Hall-Griswold 1990). Assuming a predominantly 4-year life cycle [typical for Redfish Lake sockeye salmon in the past (Bjornn et al. 1968)], adult returns may occur through at least 1993. Thus, although adult returns for the past 3 years have been minimal, we cannot make a determination that anadromous *O. nerka* are extinct in the Snake River. However, if no adults return through fall 1994 (allowing for the possibility of some 5-year-old spawners), then such a determination would probably be warranted.

THE QUESTION OF "SPECIES" UNDER THE ESA

Two key questions must be addressed in determining whether a listing under the Endangered Species Act is appropriate:

1) Is the entity in question a "species" as defined by the ESA?

2) If answer to 1) is yes, is the "species" threatened or endangered?

The ESA of 1973, as amended in 1978, allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. The Species Definition Paper for Pacific salmon (Waples 1991) stipulates that a salmon population will be considered "distinct" for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. A population (or group of populations) can be considered an ESU if it a) is reproductively isolated from other conspecific populations and b) represents an important component in the evolutionary legacy of the biological species.

Anadromy/Nonanadromy

For the sockeye salmon petition, the question of population distinctness is complicated by the presence in Redfish Lake of two forms of *O. nerka* (sockeye salmon and kokanee). The Species Definition Paper states that if both anadromous and nonanadromous forms occur together, it first must be determined whether the two forms share a common gene pool. If so, they should be considered as a unit in ESA evaluations; if the two forms are reproductively isolated, they should be considered separately. Application of the framework in the paper suggests the decision tree for the sockeye salmon petition shown in Figure 1.

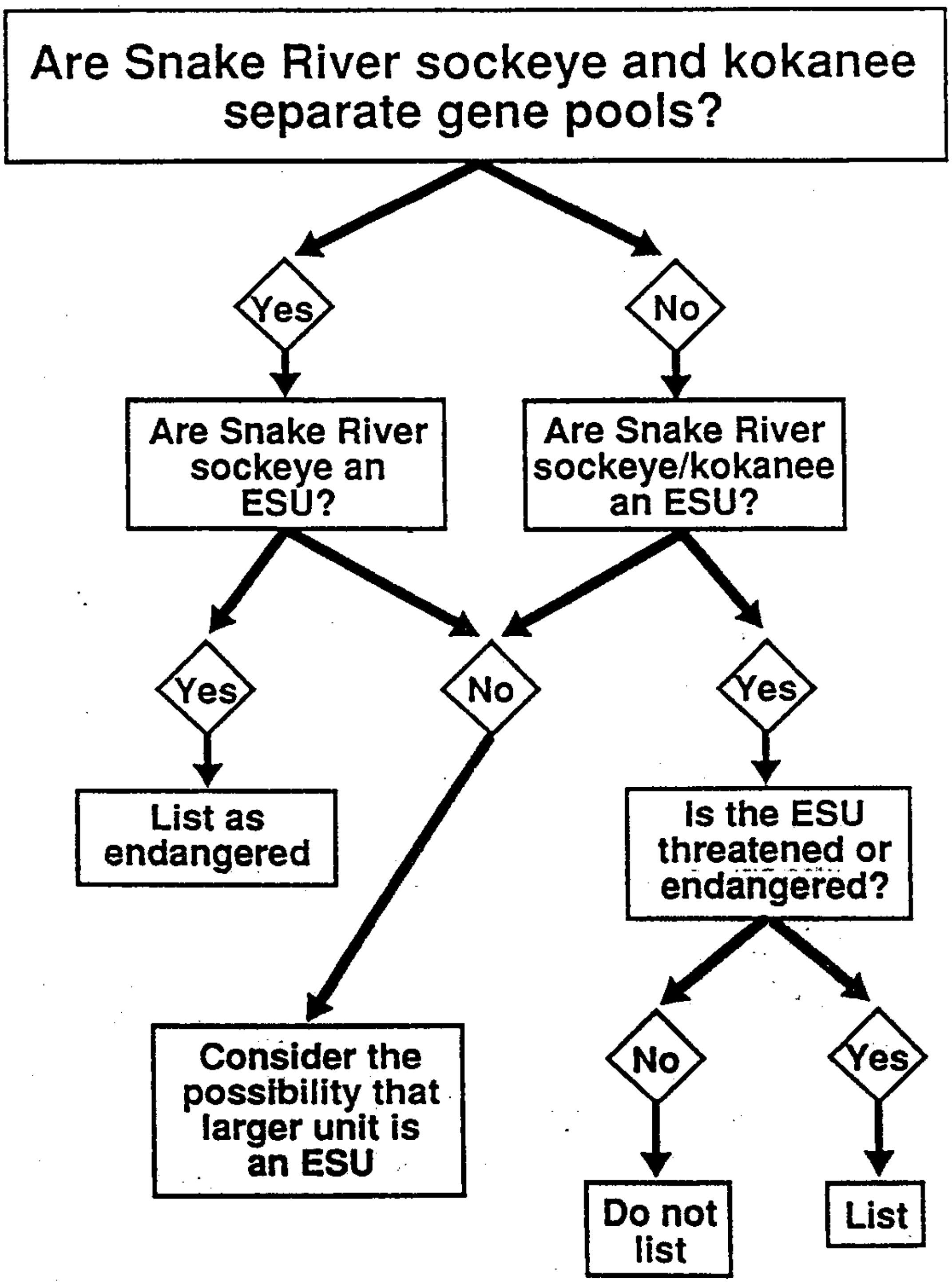

Figure 1.– Decision tree that results from applying the framework of the Species Definition Paper (Waples 1991) to the petition for Snake River sockeye salmon.

The following information is relevant to the first key question that must be addressed in the decision tree: Are Redfish Lake sockeye salmon reproductively isolated from Redfish Lake kokanee?

A. Both sockeye salmon and kokanee are native to lakes in the Stanley Basin, including Redfish Lake. Historical records (Evermann 1896) indicate that in Alturas Lake, both forms spawned in the inlet stream, with kokanee generally spawning farther upstream and sockeye salmon spawning nearer to the lake. Evermann also recorded observations of sockeye salmon spawning in August in Redfish Lake. Recent observations at Redfish Lake indicate that kokanee continue to spawn in the inlet (Fishhook Creek) in August/September, but sockeye salmon spawn later (generally October) and only along the shores of the lake (Bowler 1990).

B. Recent studies (Foote et al. 1989b) show that sockeye salmon and kokanee that spawn sympatrically can be very different genetically. Substantial genetic differences were found in spite of occasional spawning between the two forms and viability of hybrids through early life-history stages in culture (Foote et al. 1989a; Wood and Foote 1990). Foote et al. (1989b) found significant allele frequency differences between sockeye salmon and kokanee in each of the lake systems they studied that had both forms. In their study, Foote at al. (1989b) also found that the magnitude of genetic divergence between the two forms increased with distance upriver from the ocean. An electrophoretic survey conducted for this status review by NMFS also found substantial genetic differences between sockeye salmon and kokanee in the Okanogan and Shuswap river/lake systems (Monan 1991).

C. Studies of other salmonid species have shown genetic differentiation between anadromous and nonanadromous forms that occur in the same river/lake systems (Skaala and Naevdal 1989; Vuorinen and Berg 1989).

The Biological Review Team concluded it is likely (but has not been conclusively established) that prior to 1900, sockeye salmon in Redfish Lake were reproductively isolated from kokanee.

Influence of Sunbeam Dam

The present day relationship between sockeye salmon and kokanee in Redfish Lake is uncertain. No sockeye salmon were available for genetic or other analyses to compare with the kokanee that were sampled in the fall of 1990. Recent sockeye salmon in Redfish Lake may be descended directly from the pre-1900 sockeye salmon gene pool. Alternatively, Sunbeam Dam may have caused extinction of the original gene pool, and recent sockeye salmon in the Stanley Basin may be due to strays or transplants, or they may represent an anadromous form recently derived from the kokanee gene pool. The following are facts regarding Sunbeam Dam:

A. The dam was built in 1910 on the main Salmon River, about 20 miles downstream from Redfish Lake. The dam was too high for salmon to surmount by leaping.

B. A wooden fish ladder was constructed in 1912, but contemporary reports suggested that the ladder functioned poorly, if at all, for fish passage (Chapman et al. 1990).

C. A concrete fish ladder was completed in 1920. After initial structural problems were rectified, sockeye salmon and other salmonids were observed passing above the dam in that year (Pearson 1921). Apparently, concerns about fish passage persisted in subsequent years (Chapman et al. 1990), but, apart from the eyewitness accounts discussed below, there is no firm evidence regarding the effectiveness of the second ladder in the period 1921-34.

D. A diversion tunnel existed for at least part of the period 1910-34 and may have permitted passage of some species in some years.

E. The dam was partially blown out by dynamite in 1934, allowing passage of fish. Passage was further improved by removal of additional parts of the dam in subsequent years.

F. Eyewitnesses recently interviewed recall seeing sockeye salmon spawning in Redfish Lake in 1927, 1928, 1929, 1930, 1933, 1934, 1935, and 1938 (Jones 1991). Parkhurst (1950) reported adult sockeye salmon in the lake in 1942, and runs were abundant in some years in the 1950s (Bjornn et al. 1968). No information about sockeye salmon abundance in Redfish Lake is available for the period 1943-53.

Post-Sunbeam Dam sockeye salmon

A number of hypotheses have been suggested to explain post-Sunbeam Dam sockeye salmon in Redfish Lake. It was apparent from discussions in meetings of the ESA Technical Committee that there is a diversity of opinion on this subject in the scientific community. Arguments for and against each of the hypotheses can be summarized as follows:

1) Enough sockeye salmon were able to pass above Sunbeam Dam to sustain the run, either over the inadequate ladder or through the diversion tunnel.

Supporting arguments:

a) Passage of sockeye salmon in 1920 indicates that adults were present at the base of the dam 10 years after its construction, including the period during which fish passage was deemed least likely. The improved ladder completed in 1920 should have allowed easier passage in subsequent years.

b) Several eyewitnesses recall seeing adult sockeye salmon moving through the ladder and spawning in Redfish Lake between 1927 and 1933, and others recall that sockeye salmon were speared in nearby Decker Creek in 1927 and 1928 (Jones 1991).

Counter arguments:

a) The concrete ladder was not built until 1920; prior to that time, the only possibility for passage was through a diversion tunnel of uncertain utility. The wooden fish ladder installed shortly after completion of the dam was destroyed by the first high water. Fish passage through the diversion was considered difficult or impossible (Chapman et al. 1990).

b) Eyewitness accounts related 60+ years after an event may be unreliable. Perceptions of "big" and "little" (e.g., in differentiating sockeye salmon from kokanee) may be distorted by the passage of time, particularly if the eyewitness was a child at the time of the observation.

c) Even if a few sockeye salmon passed the dam between 1910 and 1934, it was not enough to maintain the run.

2) Sockeye salmon continued to spawn in the river or in refuge lakes below Sunbeam Dam during the years the river was obstructed, and descendants of these fish recolonized the lake after removal of the dam.

Supporting arguments:

a) Riverine spawning sockeye salmon are present in many areas throughout the range of the species (Foerster 1968).

b) There are lakes downstream from Sunbeam Dam (e.g., Sullivan Lake) which might have served as temporary refugia.

c) Irrigation for cattle and farming changed the hydrology of central Idaho. It is possible that prior to this period, there were other lakes or deep pools available for marginal sockeye salmon spawning.

Counter arguments:

a) Rearing habitat for sockeye salmon is not ideal (perhaps not even suitable) anywhere immediately below Sunbeam Dam.

b) If refugia were used, why aren't sockeye salmon currently observed in these areas?

3) Redfish Lake was reseeded after partial demolition of Sunbeam Dam by sockeye salmon straying from elsewhere.

Supporting argument:

Straying has been documented in sockeye salmon, as in other species in the genus.

Counter argument:

It is necessary to postulate a substantial number of strays that fail to home accurately by an enormous distance (over 700 river miles from Lake Wenatchee to Redfish Lake). No evidence has been presented to indicate that Columbia River salmon stray any substantial distance up the Snake River.

4) Post-Sunbeam Dam sockeye salmon are the result of introductions of unknown origin.

Supporting argument:

Idaho Department of Fish and Game (IDFG) has records of kokanee plants into Redfish Lake each decade beginning in the 1920s (Bowler 1990). Unrecorded plants involving sockeye salmon may also have occurred. Sockeye salmon eggs from Babine Lake, British Columbia, were introduced into nearby Alturas and Stanley Lakes in the early 1980s.

Counter argument:

The recent stocking of sockeye salmon eggs is not thought to have produced any returning adult fish (Hall-Griswold 1990). In any case, these transfers are too recent to explain the resurgence of sockeye salmon in Redfish Lake dating to at least 1942 (Parkhurst 1950) or earlier (eyewitness accounts). There is no evidence to support the speculation that sockeye salmon were introduced into Redfish Lake between 1934 and about 1950, and no one has strongly advocated this position.

5) Post-Sunbeam Dam anadromous *O. nerka* originated from the seaward drift of kokanee from Redfish Lake or other Stanley Basin lakes.

Supporting arguments:

a) Kokanee have successfully outmigrated and returned as sea-run adults in other lake systems (Foerster 1947; Mullan 1986).

b) In some years, *O. nerka* juveniles outmigrated from Redfish Lake in numbers higher than can plausibly be explained by the number of spawning sockeye salmon (Bjornn et al. 1968).

c) Juvenile kokanee migrate out of nearby Alturas Lake (Bowler 1990), and Bjornn et al. (1968) suggested that anadromous *O. nerka* found in Alturas Lake in 1964 were derived from kokanee.

d) If the original sockeye salmon gene pool became extinct as a result of Sunbeam Dam, recent anadromous fish must be derived from the kokanee gene pool because other explanations for their existence are not plausible.

Counter arguments:

a) Although it has long been known that kokanee can produce anadromous fish, the number of outmigrants that successfully return as adults is typically quite low. In fact, there appears to be no evidence that kokanee anywhere have naturally produced a sustained run of sockeye salmon. Thus, if kokanee were responsible for post-Sunbeam Dam anadromous *O. nerka* in Redfish Lake (a run that numbered over 4,300 adults in 1955), it would be an unprecedented occurrence for the species.

b) The relatively poor performance of anadromous kokanee may reflect genetically-controlled life-history differences between sockeye salmon and kokanee that are likely to influence survival in the ocean and during migration (Foote et al. 1989a; Wood and Foote 1990). If this is so, particularly poor performance might be expected from kokanee facing the long migration required for anadromous fish from Redfish Lake.

c) Other Snake River kokanee populations (e.g., Dworshak Reservoir) regularly produce outmigrants without any records of the return of adult anadromous fish (Bowler 1990).

d) In the year with the greatest excess of outmigrants in comparison with estimated sockeye salmon production, kokanee outmigration may have been influenced by release of hatchery kokanee into Redfish Lake (Bjornn et al. 1968).

e) Currently, Redfish Lake kokanee spawn in Fishhook Creek in August, whereas sockeye spawn only in the lake and primarily in October (Bowler 1990). For the "seaward drift of kokanee" hypothesis to be tenable, therefore, it is necessary to postulate substantial shifts in time and place of spawning.

6) The present gene pool is a mixture resulting from hybridization of kokanee and sockeye salmon that failed to outmigrate.

Supporting arguments:

a) In some lakes, kokanee and sockeye salmon remain sympatric and spawn in the same locations at the same time (Ricker 1940; McCart 1970; Foote 1987; Foote and Larkin 1988).

b) Kokanee males may "sneak in" on spawning sockeye salmon pairs and may fertilize sockeye salmon eggs (Hanson and Smith 1967; Foote et al. 1989a).

c) Although Foote et al. (1989b) found significant genetic divergence between sockeye salmon and kokanee in each system they examined, they also found that sockeye salmon and kokanee from the same system were more similar to each other than either was to the same form in a different drainage.

d) McCart (1970) showed that crosses between kokanee males and sockeye salmon females produce viable offspring in culture.

e) In many lakes, a percentage of sockeye salmon (principally males) fail to outmigrate, thus becoming resident fish. Residual sockeye salmon have many kokanee characteristics but may be phenotypically distinct (Foerster 1968).

Counter arguments:

a) There are observed protein electrophoretic differences between some sympatric sockeye salmon and kokanee populations which could not persist if hybrids had any appreciable degree of reproductive success (Foote et al. 1989b).

b) Kokanee and sockeye salmon spawning in the same lake system often are spatially and/or temporally isolated.

Discussion

These six hypotheses suggest three general scenarios for post-Sunbeam Dam sockeye salmon in Redfish Lake: Scenario A--the original sockeye salmon gene pool persisted (Hypotheses 1 and/or 2); Scenario B--the sockeye salmon came from somewhere else (Hypotheses 3 and/or 4); and Scenario C--recent anadromous fish are derived from the kokanee gene pool, either directly or through hybridization (Hypotheses 5 and/or 6). We rejected Scenario B because Hypothesis 3 (straying) was considered implausible given the distance from possible seed populations, and there seems to be no evidence to support Hypothesis 4 (stock transfer). Arguments can also be made against each of the remaining hypotheses; however, the post-Sunbeam Dam existence of an anadromous run of *O. nerka* in Redfish Lake is not in doubt, so they must have come from somewhere. In the judgment of the Biological Review Team, Hypotheses 1 (limited passage) and 5 (seaward drift of kokanee) were considered the most likely, but we could not completely rule out Hypotheses 2 (spawning below the dam) or 6 (hybridization of sockeye salmon and kokanee) as possible sources for the post-Sunbeam Dam sockeye salmon. The team unanimously agreed that there is insufficient information at present to determine with any reasonable degree of certainty which (or what combination) of these events actually occurred.

The Biological Review Team thus faced a difficult problem: a decision whether the sockeye salmon petition is warranted is required by law by April 1991, but there is insufficient information for a definitive determination of the first key question in the process. After a lengthy discussion, the team reached a strong consensus that, because we cannot conclude with any certainty that the original sockeye salmon gene pool is extinct, as stewards of the resource we are obliged to make a conservative decision in this circumstance. The team was not unmindful of the implications of this decision, and we do not suggest that a lack of information should always result in a conservative decision in ESA evaluations. However, a factor that weighed heavily in these considerations was the irreversibility of the likely consequences of taking the alternative course. That is, if we were to assume that recent anadromous *O. nerka* in Redfish Lake were derived from kokanee and this assumption proved wrong, the original sockeye salmon gene pool could easily become extinct before the mistake was realized.

Species Determination

An affirmative answer to the question, Are Snake River sockeye salmon and kokanee separate gene pools? places us on the left branch of the decision tree. Focus is now on the sockeye salmon gene pool, and in particular on the question, Are Snake River sockeye salmon an ESU? The NMFS Species Definition Paper (Waples 1991) provides two criteria that must be met if a population is to be considered an ESU (and hence a "species" as defined by the ESA). Information relevant to these criteria can be summarized as follows:

A. Reproductive isolation

1) Redfish Lake sockeye salmon represent the last anadromous forms of *O. nerka* in the entire Snake River system.

2) The nearest extant sockeye salmon populations are in the Wenatchee and Okanogan river/lake systems in the upper Columbia River, over 700 river miles away.

B. Evolutionary significance

1) Redfish Lake supports the southernmost sockeye salmon population in the world. Sockeye salmon returning to Redfish Lake also travel a greater distance from the sea (almost 900 miles) and to a higher elevation (6,500 feet) than do sockeye salmon anywhere else in the world. In contrast, sockeye salmon in the Wenatchee and Okanogan river/lake systems spawn at elevations more than 4,000 feet lower. Furthermore, these upper Columbia River populations are in a different ecoregion domain (Humid Temperate Domain) than is Redfish Lake (Dry Domain) (Bailey 1980). Collectively, these data argue strongly for the ecological uniqueness (with respect to sockeye salmon) of the Snake River habitat and make it likely that the population contains unique adaptive genetic characteristics.

2) Electrophoretic studies of sockeye salmon throughout North America and Asia typically have found substantial genetic differences between sockeye salmon stocks from different river systems (e.g., Utter et al. 198[illegible] Foote et al. 1989b; Monan 1991). Furthermore, a recent study (Monan 1991) demonstrated that samples of kokanee from Redfish and Alturas Lakes are genetically similar to each other but quite distinct from samples from other lakes in Idaho, Washington, and British Columbia.

These data suggest that sockeye salmon from Redfish Lake are genetically distinct from other sockeye salmon populations.

Available information thus indicates that Redfish Lake sockeye salmon are reproductively isolated from other sockeye salmon populations, and there are several good reasons for considering them to be an evolutionarily important component of the biological species *O. nerka*. Snake River sockeye salmon therefore qualify as a "species" as defined by the ESA.

Alternative Scenario

Because of the uncertainty regarding the origin of recent anadromous *O. nerka* in Redfish Lake, we also considered the implications of following the right branch of the decision tree (sockeye salmon and kokanee share a common gene pool) under the assumption that Hypotheses 5 or 6 are correct. Under this assumption, the two forms (sockeye salmon and kokanee) should be considered as a unit, and the relevant question becomes, Are Snake River sockeye salmon/kokanee an ESU? The following data are germane to this question:

A. Introductions of kokanee into Stanley Basin lakes (including Redfish Lake) have occurred many times, beginning in the 1920s and continuing through the 1980s (Bowler 1990). Sources of many of the plants are unknown, but known sources include Anderson Ranch Reservoir, Idaho; Lake Pend Oreille, Idaho; and Flathead Lake, Montana. Sockeye salmon eggs from Babine Lake in British Columbia were planted in Stanley and Alturas Lakes (but not in Redfish Lake) in 1980-83.

B. Recent electrophoretic analyses by NMFS show that kokanee from Redfish and Alturas Lakes are genetically similar to each other but as a group are very distinct from other kokanee populations from Idaho, Washington, and British Columbia, including populations known to be sources for kokanee transfers into Stanley Basin lakes (Monan 1991). Kokanee in Alturas Lake are very distinct genetically from the Babine Lake sockeye salmon that were planted there in the early 1980s (Monan 1991). We thus have no evidence that kokanee or sockeye salmon planted into Stanley Basin lakes have had a permanent genetic influence on the kokanee stock.

C. If kokanee in Redfish Lake are producing anadromous fish that return to spawn, they apparently are the only kokanee population in the Snake River drainage that is doing so.

The genetic distinctness of kokanee from the two Stanley Basin lakes suggests a strong degree of reproductive isolation from other kokanee populations. A determination regarding evolutionary significance with respect to other *O. nerka* populations would require a more detailed study, but it seems reasonable that if we assume Redfish Lake sockeye salmon/kokanee are essentially a single gene pool, then they may represent an ESU (or part of an ESU comprising, perhaps, the Stanley Basin lakes). Is such an ESU threatened or endangered? Considering only abundance, the answer is probably not. The most recent abundance estimate for Redfish Lake kokanee is about 25,000 fish of all ages. This estimate, however, has a large variance, and the kokanee population may be vulnerable if predatory species are introduced for sport fisheries (Bowler 1990).

For anadromous/nonanadromous units, however, the threshold question is somewhat more complex. Following the guidelines of the Species Definition Paper, we must consider whether loss of a trait (e.g., anadromy or nonanadromy) would compromise the genetic characteristics of the population that make it an ESU.

Specifically, in the present case, would extinction of the anadromous form represent an evolutionarily important loss to the "species"?

Several outcomes are possible. If Redfish Lake sockeye salmon/kokanee were determined to be an ESU primarily on the basis of characteristics of the kokanee form, and this determination did not depend on the existence of an anadromous form of *O. nerka*, then the potential loss of the anadromous form would probably not constitute a threat to the ESU. However, if Redfish Lake sockeye salmon/kokanee were determined to be distinct solely (or primarily) because of the presence of the anadromous form, then potential loss of a trait that makes a population "distinct" (i.e., a "species" under the ESA) should be a legitimate ESA concern.

Again, there is not enough scientific information for a definitive determination of this issue. A trait that is important in an evolutionary sense must have a genetic basis. It seems likely that there is some genetic basis for anadromous behavior in kokanee, but this has not been clearly demonstrated. Expression of the trait seems to be controlled at least in part by environmental factors. Assuming the phenomenon does have a genetic basis, it is not clear whether the trait would be lost if no anadromous fish were to return, and if so how quickly it might be lost. Foerster (1947) showed that kokanee from Kootenay Lake retained the ability to migrate to sea and return as adults (albeit in small numbers) when forced to do so, in spite of being landlocked for thousands of years. On the other hand, it has been suggested that kokanee in Wallowa Lake in Oregon (a Snake River drainage) may have lost the ability to produce truly anadromous fish within about 20 years of the erection of barriers to adult returns (Oregon Department of Fish and Wildlife 1990).

In principle, these questions are amenable to scientific study. In practice, a substantial research effort would probably be required for a minimum of 5-10 years before any meaningful results could be anticipated.

THRESHOLD DETERMINATION

If Snake River sockeye salmon are an ESU, a decision to list as endangered seems inescapable given the records of few remaining fish. As noted above, an extinction determination would be premature at this time.

RESEARCH OPPORTUNITIES FOR 1991

The following research activities may help to formulate a recovery plan (if necessary) and may provide answers to some of the important questions relating to this petition.

A. Juveniles outmigrating from Redfish Lake (April-May)

1) Use PIT tags to study time of downstream arrival at dams.

2) Perform genetic analyses for comparison with Redfish Lake kokanee sampled in 1990.

B. Adults returning to Redfish Lake (July-September)

1) Hold in net-pens until spawning (October).

2) Perform genetic analyses on carcasses after spawning.

3) Use part of progeny from spawnings in captive brood-stock program; remainder would be released into the wild.

4) Cryopreserve male gametes for use in future years.

The PIT-tag study may yield information that will allow effective use of protective measures. Genetic analysis of outmigrating *O. nerka* may show they are distinct from the resident kokanee, lending strong support to the hypothesis that another gene pool (presumably the ancestral sockeye salmon gene pool) persists in Redfish Lake. Inability to find genetic differences between 1991 outmigrants and kokanee sampled from the spawning grounds in 1990 would be consistent with the hypothesis that anadromous fish have been produced by the kokanee population. However, such a result would also be consistent with the hypothesis that no sockeye salmon outmigrated in 1991 but some remain at sea and may return through 1993. That is, fish outmigrating in 1991 might be kokanee that would never return as adults [as apparently occurs, for example, at Dworshak Reservoir (Bowler 1990)].

If an adequate number of returning adults are sampled without finding any appreciable differences from Redfish Lake kokanee, an answer of "not reproductively isolated" to the first key question is probably warranted, indicating that the right branch of the decision tree should be followed. This conclusion is based on the observation that sympatric sockeye salmon and kokanee can be quite different genetically, so we would expect to find genetic differences if the original sockeye salmon gene pool still exists.

Implementation of the suggested research plans is contingent on several factors. All field work must be coordinated with the appropriate state and federal agencies, and necessary permits must be obtained. Careful consideration should be given to the risks of handling juvenile and adult fish and the consequences of removing a sample of 50-100 juvenile outmigrants for genetic analysis. The benefits and risks of a captive brood-stock program should be discussed and carefully considered. Finally, funds to conduct the research, including personnel to staff the collecting weirs over extended periods of time, must be made available.

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