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THE WHITE HOUSE
WASHINGTON

DATE: 4-10-91

TO: Governor Sununu

FROM: **EDE HOLIDAY** 
**Assistant to the President
and Secretary of the Cabinet**

Per your request, please see the
attached data on the sockeye salmon.
Thanks.

Attachment

PACIFIC SALMON

AND THE

ENDANGERED SPECIES ACT



ADULT SOCKEYE

D = OCEAN COLOR

H = SPAWNING COLOR

PACIFIC SALMON AND THE ENDANGERED SPECIES ACT

There are five species of Pacific salmon in the western U.S. As anadromous fish, each salmon hatches and spends its juvenile stage in freshwater, migrates to the ocean, and returns to the freshwater stream of its birth at maturity to spawn and to die. Each of the five species is further divided into various "runs" according to the river system and time of the year it makes its spawning run from the ocean. Thus, the spring run of upper Columbia River chinook salmon is physically separated at the time of spawning from the fall run of the same species in the same river system.

The Endangered Species Act (ESA) defines the term "species" as including "any distinct population segment of any species of vertebrate fish or wildlife that interbreeds when mature." This definition presents special problems of interpretation when applied to the unique life cycle of Pacific salmon. Conceivably, each run of each species to each river could be considered a "distinct population segment" requiring protection under the Act whenever its population significantly declined.

The first stock of Pacific salmon listed under the ESA was the upper Sacramento River winter run chinook. It was listed as a threatened species in 1989, a fact that is now affecting dam and irrigation operators in that river.

In April 1990, the Shoshone-Bannock Tribes of Idaho filed a petition seeking to list the Snake River sockeye salmon under the ESA. NOAA determined that this petition presented substantial information suggesting that a listing was warranted and began a public process of evaluating its status. Seven environmental organizations filed petitions in June 1990 seeking to list three runs of Snake River chinook salmon and one run of lower Columbia River coho salmon. Decisions regarding the status of these four runs are due in June 1991.

In addressing each of these petitions, NOAA has attempted to avoid the experience of the Fish and Wildlife Service in listing the spotted owl. We have had an open public process. Biologists from the state fishery agencies, other Federal agencies, the Indian tribes, public utilities, and other interested entities have provided information, peer review and public comment throughout the decision-making process.

Since there were no specific criteria for determining which of the many hundreds of salmon runs represented "distinct population segments" requiring protection under the ESA, NOAA developed an interim policy and published it in the Federal Register for comment. The Fish and Wildlife Service is developing a similar policy for dealing with terrestrial species.

Under the NOAA policy, only those runs of salmon that are substantially reproductively isolated from other runs of the same

species will be considered for listing. Further, to be listed the run must represent an important component in the evolutionary legacy of the species.

Under the criteria proposed, the Snake River sockeye qualifies as a distinct population. It is the only stock of sockeye salmon in the Snake River system and its spawning run represents the longest distance, highest elevation, and most southern extreme of the sockeye species. Moreover, this run of sockeye is certainly endangered. Only two sockeye nests were observed in 1989. No nests were observed in 1990. The Snake River sockeye already may be extinct, but that cannot be confirmed until 1994 when the last of the 1989 year class would be expected to return to spawn.

The attached documents provide additional information concerning the process NOAA is using to comply with the ESA, the policy we are following to evaluate whether the various runs of Pacific salmon require listing, and the Federal Register notices that have been filed thus far.

By April, 1992, NOAA must reach a final determination on the following: (1) whether the Snake River sockeye is a "distinct population segment," (2) whether the run is endangered, and (3) what measures are necessary to avoid its extinction.

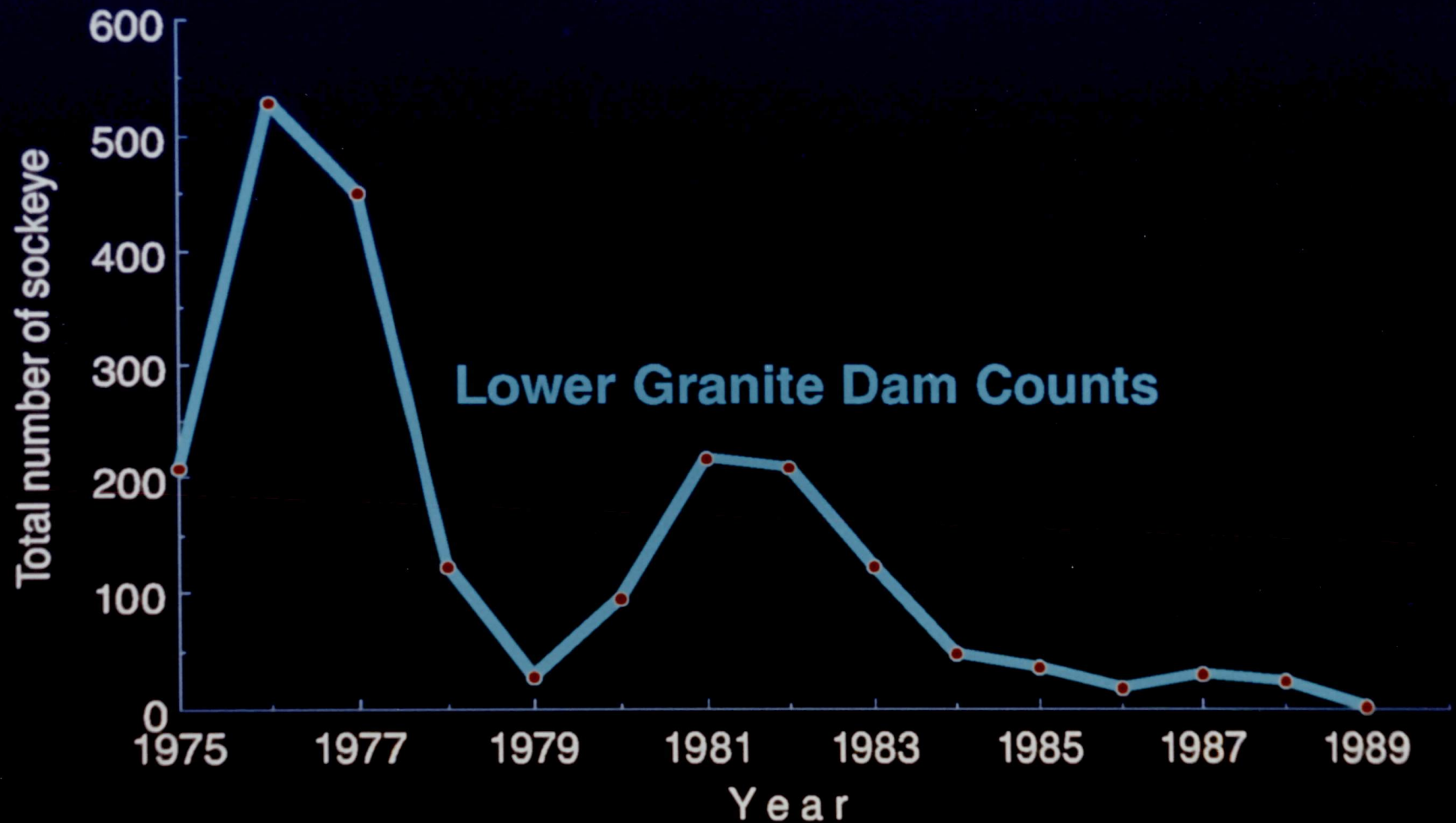
We are already far along with the process of deciding what conservation efforts will be required. Senator Hatfield has convened a so-called "Salmon Summit" from among the state and Federal agencies and the various sectors of the economy in the Pacific Northwest that will be affected by a final decision to list any or all of the five runs at issue.

At this point, the major conservation problem for Snake River sockeye appears to be management of water flows past the eight major hydroelectric dams on the Snake and Columbia River system. Those same dams adversely affect the three runs of Snake River chinook salmon whose status reviews are pending.

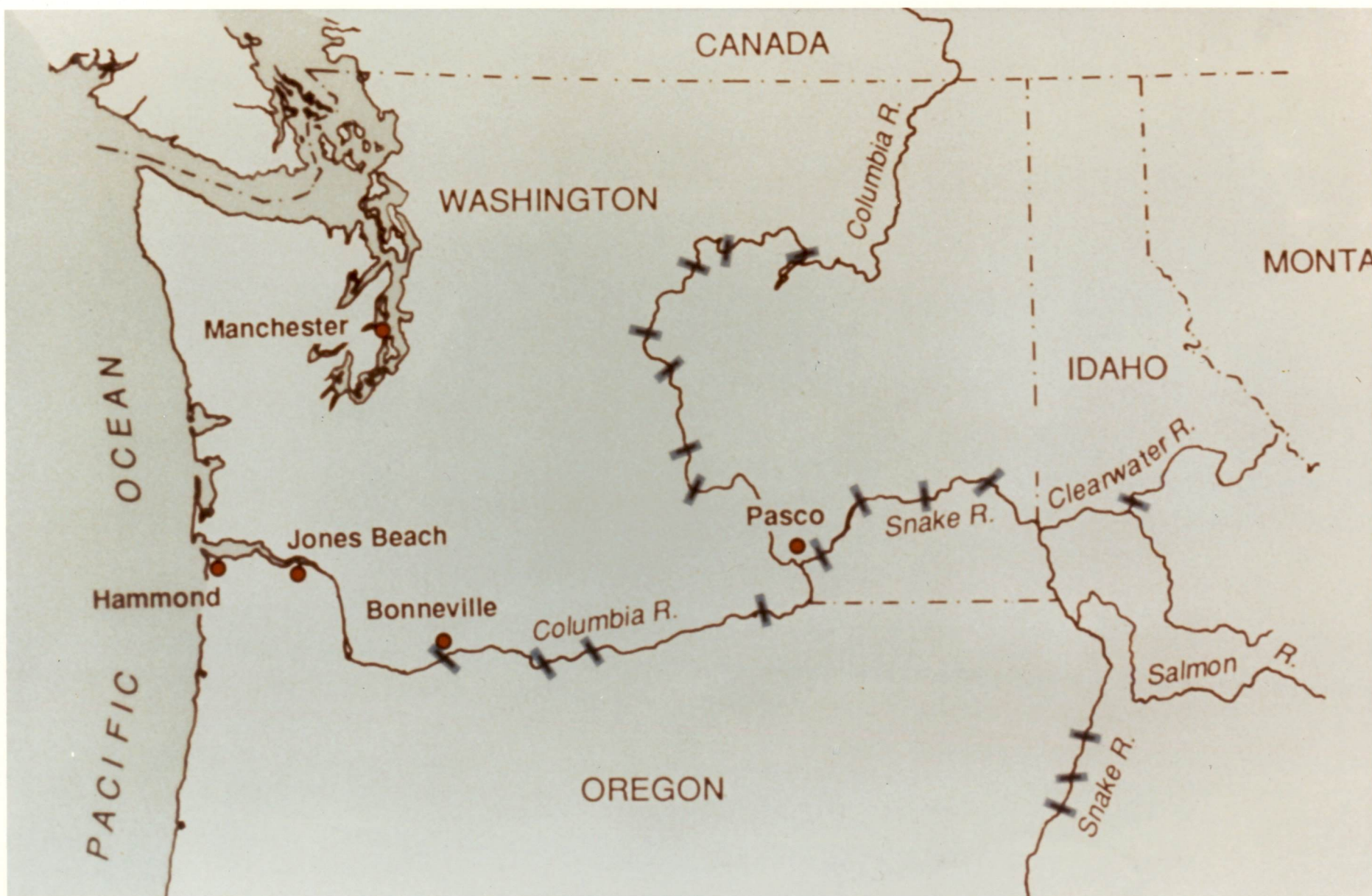
Sufficient water must be released to allow the migrating juvenile salmon to safely pass the dams on their journey to the ocean. Insufficient water flows expose too many juveniles to predation or entrainment in the hydroelectric facilities. Water diverted around the dams in order to conserve salmon will not be available to produce electricity or to irrigate farmlands.

The ESA does not permit economic factors to be considered when making a decision to list an endangered species. Such factors are pertinent to adoption of protective measures. The short-term costs of saving the Snake River sockeye and chinook salmon could be increased electric rates, loss of Federal revenues from the Bonneville Power Administration, and less water for agricultural interests. The long-term benefits could be restoration of the once productive Columbia and Snake River salmon fisheries.

Threshold determination is not an issue



ADULT SOCKEYE COUNTED AT LOWER
GRANITE DAM ON THE SNAKE RIVER



LOCATION OF MAJOR HYDROELECTRIC
DAMS ON THE COLUMBIA & SNAKE RIVER
SYSTEMS

ENDANGERED SOCKEYE SPAWN IN RED-
FISH LAKE ON THE SALMON RIVER

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

50 CFR Part 222

[Docket No.]

Endangered and Threatened Species; Proposed Endangered Status for
Snake River Sockeye Salmon.

AGENCY: National Marine Fisheries Service (NMFS), NOAA,
Commerce.

ACTION: Proposed rule.

SUMMARY: NMFS is issuing a proposed determination that the Snake River sockeye salmon (Oncorhynchus nerka) is a "species" under the Endangered Species Act of 1973, as amended, 16 U.S.C. §1531 et seq. (ESA). Furthermore, NMFS proposes to list the Snake River sockeye salmon as endangered under the ESA. The Snake River sockeye salmon has declined to extremely low numbers. Current production is limited to Redfish Lake in the Salmon River Basin in Idaho. Hydropower development, water withdrawal and diversions, water storage, commercial harvest, and inadequate regulatory mechanisms are factors contributing to the decline and represent a continued threat to the Snake River sockeye salmon's existence. Should the proposed listing be made final, the prohibitions of the ESA would be in effect and a recovery program would be implemented.

DATES: Comments from all interested parties must be received by [insert date 60 days after date of publication in the FEDERAL REGISTER]. Public hearings are scheduled as follows:

1. May 8, 1991, at 9:30 a.m., Seattle, Washington;
2. May 9, 1991, at 9:30 a.m., Portland, Oregon;
3. May 10, 1991, at 9:30 a.m., Boise, Idaho.

ADDRESSES: Comments on this proposed rule should be sent to the Environmental and Technical Services Division, NMFS, Northwest Region, 911 N.E. 11th Avenue, Suite 620, Portland, OR 97232, or provided at any one of the public hearings. The hearings will be held at the following locations:

1. NOAA, Western Administrative Support Center, Building 9, 7600 Sand Point Way, NE, Seattle, Washington;
2. 1st Floor West Side, Federal Complex, 911 NE 11th Ave., Portland, Oregon;
3. Boise Interagency Fire Center, 3905 Vista Ave., Boise, Idaho.

FOR FURTHER INFORMATION CONTACT: Tracey Vriens, Environmental and Technical Services Division, NMFS, Portland, Oregon, 503-230-5420 or FTS-429-5420.

SUPPLEMENTARY INFORMATION:

Background

NMFS initiated a status review of sockeye salmon (Oncorhynchus nerka) in the Salmon River, a tributary of the Snake River, on April 9, 1990 (55 FR 13181). NMFS also received a petition (April 2, 1990) from the Shoshone-Bannock Tribes of the Fort Hall Indian Reservation to list Snake River sockeye salmon as endangered under the ESA. NMFS published a notice on June 5, 1990 (55 FR 22942), that the petition presented substantial scientific information indicating that the listing may be warranted and requested information from the public.

NMFS has reviewed all available scientific information pertaining to the status of Snake River sockeye salmon. To assist in this review, NMFS convened a Technical Committee to provide information and to review and comment on the data in the record. The Technical Committee consists of representatives from Federal and state fisheries agencies, Indian tribes, industries, and public interest groups that have technical expertise relevant to sockeye salmon. NMFS Northwest Region Biological Review Team has prepared a technical paper "Status Review Report for Snake River Sockeye Salmon" (Waples et al. 1991) that is available upon request (see FOR FURTHER INFORMATION CONTACT).

Snake River Sockeye Salmon

The Snake River (Redfish Lake) sockeye salmon is one of three remaining stocks of sockeye salmon in the Columbia River system, the other two being in the upper Columbia River. Snake

River sockeye salmon enter the Columbia River primarily during June and July. Arrival into Redfish Lake, which now supports the only remaining run of Snake River sockeye salmon, peaks in August and spawning occurs near the shoals along the lake's shoreline primarily in October (Bjornn et al. 1968). Shoal spawning is less typical of sockeye salmon than spawning in lake tributary or inlet streams (Foerster 1968; Scott and Crossman 1979). Kokanee, a permanent freshwater form of O. nerka, are also produced in Redfish Lake and in other Stanley Basin lakes, including Alturas, Pettit, and Yellowbelly Lakes.

Eggs hatch in the spring between 80 and 140 days after spawning. Fry remain in the gravel for 3 to 5 weeks, emerging April through May and, if hatched in inlet (or outlet) streams, move immediately into the lake, where juveniles feed on plankton for 1 to 3 years before migrating to the ocean (Bell 1986). Juvenile residence of sockeye salmon in Redfish Lake rarely exceeds 2 years (Bowles and Cochnauer 1984).

Migrants leave Redfish Lake when temperatures are between 38° to 50° F, from late April through May (Bjornn et al. 1968), and smolts migrate almost 900 miles (1440 kilometers) to the ocean, where they remain inshore or within their home river's influence zone for the early summer. Later, they migrate through the northeast Pacific Ocean (Hart 1973; Hart and Dell 1986). Snake River sockeye salmon usually spend 2 years in the ocean and return in their fourth or fifth year of life. The survival rate for Snake River sockeye salmon, from the time they migrate from

the lake to returning adults, is between 0.14 to 1.83 percent (Bjornn et al. 1968).

Consideration of Snake River Sockeye Salmon as a "Species" under the ESA

To consider the Snake River sockeye salmon for listing, it must qualify as a "species" under the ESA. The ESA defines a "species" to include any "distinct population segment of any species of vertebrate . . . which interbreeds when mature." NMFS published an interim policy (March 13, 1991; 56 FR 10542) on how it will apply the ESA species definition in evaluating Pacific salmon stocks. A salmon stock will be considered a distinct population, and hence a species under the ESA, if it represents an evolutionarily significant unit (ESU) of the biological species. The stock must satisfy two criteria to be considered an ESU: (1) It must be reproductively isolated from other conspecific population units; and (2) it must represent an important component in the evolutionary legacy of the biological species. The first criterion, reproductive isolation, need not be absolute, but must be strong enough to permit evolutionarily important differences to accrue in different population units. The second criterion would be met if the population contributed substantially to the ecological/genetic diversity of the species as a whole. Further guidance on application of this policy is contained in the NMFS paper "Definition of Species under the

Endangered Species Act: Application to Pacific Salmon" (Waples 1991).

In this case, the question of population distinctness is complicated by the presence of kokanee in Redfish Lake. One hypothesis is that the sockeye and kokanee 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.

No adult sockeye salmon from Redfish Lake were available for genetic studies to compare them with kokanee sampled from the lake in 1990. However, other evidence suggests that the two forms are distinct (Waples et al. 1991). Recent studies of O. nerka in other areas of the Pacific Northwest (Foote et al. 1989) found substantial genetic differences between the two forms, in spite of occasional cross-spawning behavior and viability of hybrids through early life-history stages in culture. Foote et al. (1989) found significant differences in the frequencies of alleles between sockeye salmon and kokanee in each of the lake systems they studied, and also found that the magnitude of genetic divergence between sympatric sockeye salmon and kokanee increased with distance upriver from the ocean. An electrophoretic survey conducted by NMFS for this status review also found substantial genetic differences between sockeye salmon and kokanee in two river/lake systems where they co-occur (Monan 1991). Thus, it is likely that, historically, sockeye salmon and kokanee were reproductively isolated in Redfish Lake. Recent

observations at Redfish Lake support the hypothesis that the two forms remain distinct. 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 (Bjornn et al. 1968; Fulton 1970; Bowler 1990).

An alternative hypothesis, that Sunbeam Dam caused the extinction of the original sockeye salmon gene pool and that recent anadromous O. nerka in Redfish Lake have resulted from the seaward drift of kokanee, was also considered (see discussion under "Status of Snake River Sockeye Salmon" below). Although it is known from studies in other geographical areas that kokanee can occasionally produce anadromous fish, the number of outmigrants that successfully return as adults is typically quite low. There is 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, it would be an unprecedented occurrence for the species (Waples et al. 1991).

Given evidence that sockeye salmon continued to pass Sunbeam Dam prior to its removal, and given the uncertainty regarding the ability of Redfish Lake kokanee to produce anadromous O. nerka in the numbers observed, NMFS is proceeding on the premise that the original sockeye salmon gene pool still exists in Redfish Lake and is distinct from the kokanee (Waples et al. 1991).

Available information indicates that Snake River sockeye salmon are also reproductively isolated from other sockeye salmon

populations and represent an important component in the evolutionary legacy of the species. The great distance (over 700 river miles (1,127 kilometers)) separating Redfish Lake from the nearest sockeye salmon populations in the upper Columbia River ensures a strong degree of reproductive isolation. There is no evidence of straying of sockeye salmon from the upper Columbia River or elsewhere into Redfish Lake (Waples et al. 1991).

Redfish Lake supports the world's southernmost natural sockeye salmon population. Sockeye salmon returning to Redfish Lake also travel a greater distance from the sea (almost 900 miles (1,448 kilometers)) and to a higher elevation (6,500 feet (1,219 meters)) than do sockeye salmon anywhere else in the world. In contrast, sockeye salmon in the upper Columbia Basin spawn at elevations more than 4,000 feet lower. Furthermore, the upper Columbia River populations are in a different ecoregion domain (humid temperate) than is Redfish Lake (dry) (Waples et al. 1991). 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 Redfish Lake population contains unique adaptive genetic characteristics.

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. 1984; Foote et al. 1989; 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 results suggest that, although the relevant data are not available for Redfish Lake sockeye salmon, this population is probably genetically distinct from other sockeye salmon populations.

NMFS concludes that the best available information indicates that this stock meets both of the criteria necessary to be considered an ESU. Therefore, NMFS is issuing a proposed determination that the Snake River sockeye salmon is a "species" under the ESA.

Status of Snake River Sockeye Salmon

Historically, sockeye salmon were produced in Idaho in the Stanley Basin of the Salmon River in Alturas, Pettit, Redfish, Yellowbelly and Stanley Lakes and may have been present in one or two other Stanley Basin lakes (Bjornn et al. 1968). Welsh et al. (1965) also included Little Redfish Lake, on Redfish Creek downstream from Redfish Lake, as sockeye salmon habitat. Outside of the Salmon River Basin, but within the Snake River Basin, sockeye salmon were produced in Big Payette Lake on the North Fork Payette River and in Wallowa Lake on the Wallowa River (Evermann 1895; Toner 1960; Bjornn et al. 1968; Fulton 1970).

In 1881, 2,600 pounds (1,180 kilograms) of fresh sockeye salmon were taken by prospectors at Alturas Lake, near Redfish Lake in the Stanley Basin (Evermann 1896). However, agricultural

diversions using all the water in Alturas Lake Creek currently prevent adult sockeye salmon from migrating upstream and eliminates production in Alturas Lake. Treatment of Pettit and Yellowbelly Lakes with piscicides (chemicals used to kill fish) in 1961 and 1962 and the operation of migration barriers to prevent warmwater fish species from reinhabiting the lakes eliminated juvenile sockeye salmon and prevented adult salmon access.

There is no reliable information on the numbers of sockeye salmon spawning in Redfish Lake in the early 1900s (Bjornn et al. 1968). However, Evermann (1895, 1896) reported that there were plans to build a cannery there.

Construction of Sunbeam Dam in 1910, 20 miles (32.2 kilometers) downstream from Redfish Lake Creek on the mainstem Salmon River, seriously impeded sockeye salmon access to the Stanley Basin lakes. The original adult fishway was constructed with wood and was ineffective in passing fish over the dam (Kendall 1912; Gowen 1914). It was replaced in 1920 with a concrete adult fishway that improved passage.

There is a difference of opinion regarding the effects of Sunbeam Dam on the original sockeye salmon run to lakes in the Stanley Basin. Some argue that the dam represented a complete barrier to upstream passage for enough years that the original anadromous run was eliminated (Chapman et al. 1990). On the other hand, eyewitness accounts (Jones 1991) document adult sockeye salmon spawning in Redfish Lake in a number of years

prior to and immediately after partial removal of the dam in 1934. Subsequently, Parkhurst (1950) reported sockeye salmon spawning in the lake in 1942.

Escapement of sockeye salmon to the Snake River has declined dramatically in recent years. Counts made at Lower Granite Dam (the first dam on the Snake River downstream from the confluence of the Salmon River) since 1975 have ranged from 531 in 1976 to 0 in 1990. It should be noted that the number of fish counted at a dam may differ from the number actually passing; some fish may pass during non-counting periods or may pass through navigation locks. Records are available on escapement into Redfish Lake for the years 1954 through 1966 and from 1985 through 1987. During these years, the Idaho Department of Fish and Game (IDFG) enumerated adult sockeye salmon at Redfish Lake weirs. In the years from 1954 through 1966, the number of adults counted by IDFG varied from 4,361 in 1955, to 11 in 1961, to 335 in 1964. In the years 1985 through 1987, IDFG operated a temporary Weir at Redfish Lake Creek. The total escapement in these years was 12 in 1985, 29 in 1986, and 16 in 1987. In 1988, IDFG also conducted spawning ground surveys that identified four adults and two redds (gravel mounds in which the eggs are deposited). In 1989, one adult was passed into Redfish Lake and one redd and a second potential redd were identified. No redds or adults were identified in 1990.

Summary of Factors Affecting the Species

An endangered species is any species in danger of extinction throughout all or a significant portion of its range; a threatened species is any species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Section 4(a) of the ESA requires that the listing determination be based solely on the best scientific and commercial data available, without reference to possible economic or other impacts of such determination. Species may be determined to be endangered or threatened due to one or more of the five factors described in section 4(a)(1) of the ESA. These factors, as they apply to Snake River sockeye salmon, are discussed below.

1. The Present or Threatened Destruction, Modification or Curtailment of its Habitat or Range.

(a) Hydropower Development. Dams and reservoirs have substantially reduced the abundance of salmon in the Columbia River Basin. The Northwest Power Planning Council (NWPPC) estimated that current annual salmon and steelhead production in the Columbia River Basin is more than 10 million fish below historical levels, with 8 million of this annual loss estimate attributable to hydropower development and operation (NWPPC 1987). The NWPPC further estimated that approximately half of the 8 million fish loss was caused by the loss of habitat blocked by Chief Joseph and Hells Canyon Dams in the upper Columbia and Snake Rivers. The remaining 4 million fish loss was attributed

to ongoing annual passage losses at and between the eight mainstem projects below Chief Joseph and Hells Canyon Dams. Although the specific number of Snake River sockeye salmon lost is unknown, they are included in the overall numbers presented by the NWPPC.

(1) Juvenile Sockeye Salmon Passage. Juvenile Snake River sockeye salmon migrants must pass eight hydroelectric projects between upriver rearing areas and the ocean. Each project includes a dam and a reservoir, both of which decrease the survival of juvenile migrants. System mortality estimates include loss at the dams and in the reservoirs. Additional impacts not included in these estimates could also occur due to sub-lethal effects attributable to passage. These sub-lethal impacts (e.g., stress, injury and delay) can affect long-term survival (Matthews et al. 1987; Johnson et al. 1990; and Hawkes et al. 1991).

Although no system mortality studies have been conducted specifically with sockeye salmon, studies have been conducted with other species of salmon in the Columbia and Snake Rivers. Studies using Snake River steelhead and chinook salmon released above the dams and later recovered in the lower Columbia River provide an annual loss estimate per project (dam and reservoir) in the range of 13 to 54 percent (average 28 percent). Assuming the average rate per project, the cumulative mortality over eight dams would be 93 percent. The greatest mortality occurred in years when Snake and Columbia River flows during the spring

migration were low. Estimates of cumulative losses of inriver migrants past eight dams approached 100 percent in these low flow years (Raymond 1979; Sims and Ossiander 1981). Similar studies with chinook salmon in the Columbia River above the confluence with the Snake River resulted in an estimated annual loss per project in the range of 13 to 25 percent (Chapman and McKenzie 1980; McKenzie et al. 1983; and McKenzie et al. 1984). The Columbia River studies included no low flow years.

Injury and mortality can occur through each dam passage route (turbines, spillways, ice and trash sluiceways, and juvenile fish bypass systems), but there are numerous studies documenting that loss rates from passage through turbines is generally high relative to the other routes of passage.

One means of avoiding juvenile losses at dams is to collect and transport juveniles around the dams. While such transportation has been shown to have positive benefits for some salmon and steelhead stocks, for other stocks, the benefit is unclear. Most of these studies used steelhead, chinook or coho salmon. No studies have been done specifically on Snake River sockeye salmon. Limited information on Columbia River sockeye salmon suggests that this species is more susceptible to physical injury and mortality in project passage and handling than are other species (Gessel et al. 1988; Johnsen et al. 1990; Koski et al. 1990; Parametrix 1990; and Hawkes et al. 1991).

Fish mortality also occurs while juveniles are in reservoirs. Causes include predation, disease, temperature, and

other factors that affect the condition of the environment or the fish at the time of their transition to saltwater. Dissolved gas supersaturation due to spill of water at the dams was also identified as a significant cause of mortality in the 1970s, but increased hydraulic capacity at the mainstem projects, greater flow control, and structural modifications to some spillways have substantially reduced this problem. Some fish also lose the urge to migrate. These fish remain in the reservoir and are lost to the migrating population.

Delay of migration during reservoir passage may also result in a loss. Because salmon and steelhead must undergo a temporary physiological change that enables them to make the transition from fresh to saltwater, delay can cause the fish to either cease migrating or to arrive at the ocean and be unable to adapt to salt water. Delay can also increase predation due to both increased exposure time and an increasing predation rate that accompanies a rise in temperatures through the spring and into summer (Columbia Basin Fish and Wildlife Authority (CBFWA) 1991).

Juvenile fish passage through reservoirs has been estimated to take one-third to one-half longer than passage through free-flowing water stretches (Raymond 1988). Delay in mainstem reservoirs is the result of low water velocity from two causes. The first is increased cross-sectional area of the river due to impounding the water above the dam. The second is the reduction in spring and summer flows due to withdrawals of water for irrigation and the use of headwater storage reservoirs to impound

water during the spring and summer snowmelt. Impounded water is used for hydroelectric power in fall and winter when the regional energy demand is greatest.

The present management of water in the Columbia River system does not provide adequate flows and velocity to move downstream migrants safely to saltwater. As a result, many stocks of salmon and steelhead (including Snake River sockeye salmon) are continuing to decline.

(2) Adult Sockeye Salmon Passage. Cumulative adult passage loss for salmon passing mainstem dams can be substantial. Analysis of adult Columbia and Snake River sockeye counts for Bonneville and Priest Rapids/Ice Harbor Dams (Ross 1991b), adjusted for commercial, ceremonial and subsistence fisheries, showed an average annual loss of 10.5 percent (2.7 percent per dam) in the lower Columbia River since completion of the last dam in this reach in 1968 (Washington Department of Fisheries and Oregon Department of Fish and Wildlife, 1990). Assuming a similar loss per project in the Snake River, an additional 8 percent loss would occur from Ice Harbor Dam to Lower Granite Dam.

Delay at dams can also be an important factor in the survival of Snake River adult sockeye salmon. Factors influencing delay include the effectiveness of fish passage facilities, powerhouse and spillway operations, flow, and water quality. Average delay for adult salmonids at a Columbia River mainstem dam is about 1 to 3 days when good passage conditions

exist (Ross 1983; Turner 1984). Average delay at a lower Snake River mainstem dam is about 1 to 2 days when little or no spill is occurring, increasing to about 5 to 7 days during high spill (Turner 1983; Turner 1984). Radio-tagged sockeye salmon had a mean passage time of 74 (range 5 to 150) hours at Bonneville Dam in 1982 (Ross 1983) and 24 (range 3 to 73) and 16 (range 2 to 49) hours at McNary and John Day Dams, respectively, in 1985 (Shew 1985).

Delay can be greater when adult passage facilities are not operated consistent with established criteria (i.e., at reduced hydraulic head and weir depths attraction flows at entrances are reduced). Inadequate water velocity inside fish ladders also increases delay. Fish Passage Center (FPC) Adult Fishway Inspections Annual Reports (1988, 1989, 1990) indicate that mainstem dam adult fishways are operating below velocity criteria a substantial amount of time (Ross 1991a).

Because sockeye salmon do not feed during their upstream migration, delays during migration may deplete limited energy reserves and reduce survival. Delays of as little as 3 to 4 days at migration barriers have been associated with pre-spawning mortality (CDE and IPSFC 1971).

Adult salmon fall back through spillways at dams can be as high as 58 percent (Monan and Liscom 1975). Most adult fish that fall back reascend the fishways and continue their migration. Fallback can also occur through turbines, which can result in mortalities of at least 22 to 41 percent (Wagner and Ingram

1973). Dissolved gas supersaturation caused by large amounts of water spilling over dams can also result in injury and death to adult salmon.

(b) Water Withdrawal and Storage. Diversion and storage of water within the Columbia River has decreased water availability and altered historical run-off patterns in the Columbia River Basin. In addition, unscreened water diversions have often permitted juvenile anadromous fish to move onto irrigated lands and be lost.

Within the Snake River system, the major consumptive use of water is for agricultural irrigation. Both Federal and private reservoirs store natural flows from the Snake River Basin for agriculture. The total annual discharge of the Snake River is approximately 36 million acre-feet (MAF) (44.4 cubic kilometers). Approximately 16 MAF (19.73 cubic kilometers) are diverted annually from the Snake River and of this, 6 MAF (7.4 cubic kilometers) are consumed by agriculture.

Total active storage (the amount of water that can be removed from a reservoir) in the Snake River Basin above Hells Canyon Dam (including Brownlee Reservoir) is approximately 11.3 MAF (13.94 cubic kilometers). The amount of active storage available for use varies from year to year, depending on rainfall and run-off. This storage alters timing of peak flows in the Snake River that would, under natural conditions, have occurred during the spring run-off when juvenile anadromous fish are migrating.

Water diversions have had a significant impact on Stanley Basin sockeye salmon populations. Chapman et al. (1990) listed agricultural diversion among the causes of the sockeye salmon's decline from all Stanley Basin lakes, including Redfish Lake. Chapman et al. (1990) notes that more than 68 agricultural diversions are present on the Salmon River and tributaries within the Sawtooth National Recreation Area (SNRA). Agricultural diversion at Busterbach Ranch, on Alturas Lake Creek in the Stanley Basin, completely de-waters the creek, totally blocking sockeye salmon from Alturas Lake (Bowles and Cochnaur 1984; Chapman et al. 1990; IDFG 1990). Screens have been installed in the Salmon River Basin since the mid-1950's to prevent fish from entering diversions (Delarm and Wold 1985). However, many Stanley Basin streams in the SNRA were not screened until the mid to late 1970s and some unscreened diversions still exist.

In the Columbia River Basin above the confluence with the Snake River, a significant amount of water is also withdrawn for agricultural irrigation. For instance, irrigation diversion at the Bureau of Reclamation's (BOR) Columbia Basin Project above Grand Coulee Dam averaged 2.3 MAF (2.84 cubic kilometers) annually between 1968 and 1987 (BOR 1989).

The BOR (1989) evaluated the impact on fishery resources from proposed increases in agricultural withdrawals at the Columbia Basin Project. By modeling smolt survival for Columbia and Snake River spring chinook and steelhead at various flows, the BOR demonstrated decreased smolt survival with increased

Columbia River agricultural withdrawal. Thus, water withdrawals from the Columbia River Basin impact the survival of juvenile salmonids by reducing flow during the time they migrate through the Columbia River to the ocean.

2. Over-utilization for Commercial, Recreational, Scientific or Educational Purposes. Data specific to the exploitation of Snake River sockeye salmon are limited, but available information indicates that commercial fisheries in the lower Columbia, and harvest on the spawning grounds, were primary factors in the decline of Columbia River sockeye salmon (Fulton 1970).

The sockeye salmon fishery in the lower Columbia River began in 1889 and peaked in 1898 when harvest exceeded 4.5 million pounds (2.04 million kilograms) (Fulton 1970). Between 1905 and 1930, sockeye salmon production in the Columbia River Basin was effectively limited to the Wenatchee, Osoyoos/Okanogan, and Salmon River systems following the construction of barriers to fish passage in the Yakima, Payette, Wallowa, and Arrow Lakes systems.

In the years from 1960 to 1973, commercial and tribal sockeye salmon fisheries in the Columbia River, downstream from the Snake River, averaged 35,956 fish. Non-treaty and treaty commercial fisheries for sockeye salmon were closed from 1974 through 1983. Harvest figures for tribal ceremonial and subsistence fisheries were first reported in 1977 and averaged more than 1,000 fish annually and ranged up to 2,131 fish (1984)

through 1990. From 1975 to 1983, annual sockeye salmon counts over Lower Granite Dam averaged 221 fish, ranging from 25 to 531. Commercial fisheries for sockeye salmon resumed in 1984 and escapement over Lower Granite Dam from 1984 to 1989 declined to an annual average of only 26 fish, (ranging from 2 to 49).

Salmon River sockeye salmon generally comprised less than 1 percent of the sockeye salmon entering the Columbia River between 1954 and 1966 (Bjornn et al. 1968). It is likely that Salmon River, Wenatchee and Osoyoos/Okanogan sockeye salmon have overlapping inriver migration timing and therefore are harvested at similar rates (ODFW and NMFS 1990). Considering the low abundance of Salmon River sockeye salmon relative to Wenatchee and Osoyoos/Okanogan River sockeye salmon, and their similarly timed migration, Salmon River sockeye salmon may be subjected to excessive exploitation during inriver fisheries. Bjornn et al. (1968) reported that the number of adults returning to Redfish Lake appeared to be related somewhat to the fisheries in the lower Columbia River. A disproportionately high number of Redfish Lake sockeye salmon may have been harvested since Columbia River fisheries were selective for larger fish and Redfish Lake sockeye salmon are relatively large compared to Columbia River sockeye salmon (Bjornn et al. 1968).

The recreational harvest of sockeye salmon in the Columbia River is negligible (Washington Dept. of Fisheries and Oregon Dept. of Fish and Wildlife 1990).

The ocean harvest of sockeye salmon is believed to be

relatively insignificant. The catch of all Pacific salmon off Oregon, Washington, and California includes fewer than 100 sockeye salmon annually (Pacific Fishery Management Council 1990). Other possible areas of ocean catch are in the high seas driftnet fishery and the troll fishery off British Columbia. Although no information is available to identify Snake River sockeye salmon in these high seas and British Columbia catches, the numbers of Snake River sockeye would be expected to be low.

Based on existing records, NMFS concludes that fisheries (other than recreational) in the Columbia River and near the spawning grounds have contributed to the decline of Snake River sockeye salmon.

3. Disease or Predation.

(a) Disease. Sockeye salmon are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, migratory routes, and the marine environment. Specific disease pathogens such as infectious hematopoietic necrosis virus, Flexidacteras columnaris, Tricophera sp., Ceratomyxa shasta, as well as others are known to be present. Even though O. nerka is susceptible to these, their effect on Snake River sockeye salmon not documented.

(b) Predation. While predation has been investigated for Columbia and Snake River juvenile and adult salmon migrants in general, little information exists for Snake River sockeye runs specifically. However, because juvenile Snake River sockeye salmon migrate with other Columbia River spring and summer

migrating salmon, the rate of predation should be similar for all of these species.

(1) Freshwater Predation. There are several causes of increased freshwater predation on juvenile salmonids. Non-native predatory species such as walleye (Stizostedion vitreum vitreum) have been introduced into the Columbia River system. Native predator populations, including northern squawfish (Ptychocheilus oregonensis) and several species of fish-eating birds, have benefitted from dam impoundments that provide foraging areas. Furthermore, various bird species, such as gulls (Larus sp.) and common mergansers (Mergus merganser), prey on juvenile salmonids in their natal streams and migration corridors. Turbulence at turbine and dam bypass outlets and spillways has increased predator success by disorienting juvenile migrants (Poe et al. 1988). Slack water conditions in reservoirs have increased smolt travel time, resulting in an increased exposure to resident predators.

Studies in John Day Reservoir indicated that native northern squawfish were the primary predator of juvenile salmonids, but introduced predators such as walleye, smallmouth bass (Micropterus dolomieu), and channel catfish (Ictalurus punctatus) also took significant numbers of smolts. These predators were estimated to consume between 9 and 19 percent of the juvenile salmonids entering the reservoir, with northern squawfish accounting for approximately 78 percent of this loss (Poe et al. 1988).

Predation on eggs, fry, and pre-smolt sockeye has been estimated in Alturas Lake at up to 60 percent. This was primarily due to large populations of rainbow trout (Oncorhynchus mykiss) and dolly varden (Salvelinus malma) (Bowles and Cochnauer 1984). Alturas and Redfish lakes were stocked with Kamloops rainbow and eastern brook trout (Salvelinus fontinalis) (IDFG Biennial reports 1923-1942), both of which eat fish (Scott and Crossman 1979). Freshwater predation is a factor contributing to the decline of sockeye salmon in the Snake River.

(2) Marine and Estuarine Predation. Marine and estuarine predation of salmonids in general has been extensively investigated, but again, very little information exists for Snake or Columbia River sockeye salmon stocks. NMFS has noted that marine mammal numbers, especially harbor seals and California sea lions, are increasing on the West Coast and increased predation by pinnipeds has been noted in all Northwest salmonid fisheries (NMFS 1988). In 1990, an average of 18 percent of the fish examined at Lower Granite Dam on the Snake River had bite marks thought to be from sea lions (Harmon and Matthews 1990). Of the 34 species of marine mammals known to frequent all salmon occupied waters, 15 are known to prey on salmon (Fiscus 1980). The salmon shark (Lamna ditropis) and Pacific hake (Merluccius productus) are also thought to be important predators of sockeye salmon (Gilhousen 1989, Beachum 1989). Predation by birds on downstream migrants also occurs in the estuary. Information is not available to determine if marine and estuarine predation has

any measurable impact on Snake River sockeye salmon.

4. Inadequacy of Existing Regulatory Mechanisms. There is a wide variety of Federal and state laws that impact the abundance and survival of anadromous fish populations in the Columbia River. These laws, such as the Fish and Wildlife Coordination Act, the Federal Power Act, the Pacific Northwest Electric Power Planning and Conservation Act of 1980 and the Water Resources Development Act, concern fish resource measures at water resource developments, including hydropower projects. Other Federal laws applicable to Snake River sockeye salmon include the National Environmental Policy Act, Federal Water Pollution Control Act, and the Salmon and Steelhead Conservation and Enhancement Act. Some of these laws are summarized below. None of these laws has proven sufficient to prevent the decline of Snake River sockeye salmon.

(a) Fish and Wildlife Coordination Act (16 U.S.C. 661-666c) (FWCA). The FWCA requires that wildlife conservation receive equal consideration and be coordinated with other features of water-resource development programs. Federal water development and permitting and licensing agencies are to seek the recommendations of the Federal and state fish and wildlife agencies for mitigation and enhancement of fish and wildlife resources. These recommendations are to be given "full consideration." However, because acceptance of the fish and wildlife agencies' recommendations is not mandatory, they are not always adopted, particularly when they affect another purpose for

which a project may be authorized. While the coordination required by the FWCA has been helpful, it is not adequate to protect Snake River sockeye from the harmful impacts of water development activities.

(b) Federal Power Act (16 U.S.C. 791-825) (FPA). Non-Federal dam construction and operation for hydropower is authorized by the FPA. Like the FWCA, fish and wildlife agencies have the authority to make recommendations pertaining to project construction and operation actions affecting fish and wildlife. The fish and wildlife agencies' authority was strengthened by the Electric Consumer's Protection Act of 1986, which requires the Federal Energy Regulatory Commission to include conditions in each license, based on fish and wildlife agencies' FWCA recommendations, to equitably protect, mitigate and enhance fish and wildlife.

The Hells Canyon Complex, licensed under the FPA, is currently owned and operated by the Idaho Power Company, and consists of Hell's Canyon, Oxbow, and Brownlee Dams. The Hell's Canyon Dam, the most downstream dam, poses a complete barrier to anadromous fish passage. The complex was authorized under a single FPA license in 1955. At the time of licensing, there were no downstream Federal dams in the mainstem Snake River and minimum flow requirements for juvenile migration were not included in the license. Modifying the license to include flows adequate for migration would take many years, based on experience with other modification proceedings. The only automatic

opportunity for changing the license conditions will come with the project's relicensing, which will likely occur in 2005, at the end of the license's 50-year term.

The overall impact of the FPA has been to increase the number of Columbia River Basin hydropower facilities--some of which adversely impact migrating salmonids, including Snake River sockeye salmon.

(c) Salmon and Steelhead Conservation and Enhancement Act of 1980 (16 U.S.C. 3301 et seq.). This Act authorized formation of a Salmon and Steelhead Advisory Commission (SSAC) comprised of state, tribal, Federal, and Pacific Fishery Management Council representatives. It was charged with preparing a comprehensive report for developing a coordination and management structure to address salmon and steelhead stocks of Washington and the Columbia River. The report was to be approved by the Secretary of Commerce (Secretary), and, if an effective management structure could be established, participating agencies would be eligible to receive additional funds for "enhancement" activities.

A report was prepared and submitted to the Secretary for approval. The Secretary returned the report to the SSAC for further work, but funds supporting the SSAC had been spent and no further action was taken. No additional funds were appropriated by Congress for continued work on the report or for constructing enhancement facilities.

While the effort of the SSAC was very useful in developing

closer coordination of anadromous fish activities among the agencies, it was inadequate in providing any additional protection to upper Columbia River salmonids.

(d) Mitchell Act (16 U.S.C. 755-757). The Mitchell Act was intended to compensate for the progressive decline of Columbia River Basin salmonid resources due to destruction of favorable environmental conditions by hydroelectric development, deforestation, pollution, and water diversions. The Columbia River Fisheries Development Program, administered by NMFS under the Mitchell Act, has a number of successful programs that implement stream improvements, screening of irrigation diversions (some of which have been in the Salmon River basin) and hatchery operations. Although the Mitchell Act has increased fish production and survival, it is limited to screening, stream improvement, and artificial propagation, and alone is inadequate to deal with the comprehensive needs of the Columbia and Snake River Basin salmon problems.

(e) State Laws. The implementation of the state laws of Oregon, Washington, and Idaho that affect water allocation, water quality, and riparian and wetland protection are very important to the conservation of salmon. One example of water use management that has adversely affected Snake River sockeye salmon is the Busterbach Ranch agricultural diversion, which de-waters Alturas Lake Creek, and prevents sockeye salmon from returning to Alturas Lake.

State laws that require screening of irrigation diversions

may also be inadequate. For example, it is illegal in the State of Idaho to receive or take more than 125 cubic feet per second (cfs) (3.54 cubic meters per second) of water from any stream or lake without installing and maintaining a screen to prevent fish from entering therein. For smaller diversions, Idaho state law permits construction and maintenance of irrigation screens by the IDFG. For comparison, the State of Oregon requires diversions of more than 30 cfs (0.85 cubic meters per second) to be screened when gamefish exist. Since the early 1950s, NMFS has been working with the State of Idaho, through the Columbia River Fisheries Development Program, to install screens on approximately 236 diversions in the Salmon River Basin. However, there are still unscreened diversions.

(f) Harvest Regulation. The only direct fishery harvest on Columbia River Basin sockeye salmon is the mainstem river fishery under the management responsibility of the states and the four tribes that are parties to U.S. v. Oregon (302 F. Supp. 899 (D.Or. 1969), aff'd, 529 F.2d 570 (9th Cir. 1976)).

(g) Pacific Northwest Electric Power Planning and Conservation Act of 1980 (16 U.S.C. 839 et seq.) (NWPAA). The NWPAA was passed to encourage efficiency, coordination and regional participation in power planning in the Pacific Northwest while providing protection, mitigation and enhancement of affected fish and wildlife, especially anadromous fish. The NWPAA specifically requires that fish and wildlife resources be given equitable treatment in management, operation and regulation of

the Columbia River hydroelectric power system. It also requires the development of a comprehensive program to protect, mitigate and enhance fish and wildlife in the Columbia Basin. The NWA established the Northwest Power Planning Council (NWPPC) to coordinate power planning and fish and wildlife measures.

In 1982, in accordance with section 4(h) of the NWA, the NWPPC adopted a Fish and Wildlife Program (FWP) based on recommendations of the Region's Federal and state fish and wildlife agencies and Indian tribes. The agencies responsible for managing, operating and regulating Federal and non-Federal hydroelectric facilities in the Columbia River Basin are responsible for implementing the FWP.

In the case of anadromous fish, the NWA specifically recognized the need for "improved survival . . . at hydroelectric facilities" and the need for "flows of sufficient quality and quantity between such facilities to improve production, migration and survival."

There are two reasons why the NWA has not achieved positive results for the survival of anadromous fish: (1) There is no mandate requiring compliance with the FWP--the NWA only requires that measures be taken into account to the fullest extent practicable; and (2) the lack of specificity in program measures often leads to disagreements over interpretation of how measures are to be implemented. Below is a summary of some of the FWP's more important features.

(1) Water Budget. Mortality of juvenile fish during their

seaward migration is a major problem confronting upper Columbia River stocks, such as Snake River sockeye salmon. Flow is important because delays caused by the combination of flow regulation (storing high natural runoff in the spring and early summer to provide regulated releases for power generation in the fall and winter) and changes in river cross-sectional area (from a free-flowing river to a series of impoundments) result in reduced survival. Passage at the dams is also a problem. Estimates of losses due to passage through turbines at these projects have ranged from 8 to 32 percent (Bell 1981; Long 1968). When the NWPPC solicited recommendations for provisions of the FWP, the fishery agencies and tribes recommended specific minimum and optimum flow levels for each month, with a sliding scale (which would provide additional water in years with better flows) for the critical juvenile fish migration period, April 15 through June 15. The NWPPC response to the agencies' recommendation was to include a "water budget" in the FWP.

The water budget is a specified volume of water to be managed by the fish and wildlife agencies and the tribes and released between April 15 and June 15 to aid the downstream migration of anadromous fish in the Columbia River. It consists of a Snake River component of 1.19 MAF (1.43 cubic kilometers) and a Columbia River component of 3.45 MAF (4.26 cubic kilometers). The greater volume of Columbia River water supplements the Snake River releases in providing flows in the mainstem Columbia River below the mouth of the Snake River. A

water budget has been included in planning for Columbia River water management since 1984. The NWPPC did not address flows outside the April 15 to June 15 period, reasoning that flows from power generation during the rest of the year would be sufficient to provide for fish passage (NWPPC 1984).

While the water budget has been beneficial in improving fish passage and survival, its potential has not been achieved due to a number of problems in both design and implementation. Problems include inadequate amounts of water, the limitation to a 60-day period, the lack of a guaranteed firm base flow, changes by the implementing agencies of the NWPPC-established priorities for water use, and constraints imposed by the operators (such as the Corps of Engineers and the Idaho Power Company) on how water is released.

(i) Inadequate amount of water. The NWPPC purposely set the water budget for Lower Granite Dam in the Snake River lower than fishery agency and tribal recommendations for minimum flows due to concerns about the impact on reservoir refill (NWPPC 1984). Further, the amount of water specified in the water budget is not always provided. For example, the water budget provides for 1.19 MAF (1.43 cubic kilometers) in the Snake River, but the amount actually obtained has ranged from 0.44 to 0.48 MAF (0.52 to 0.59 cubic kilometers). This amount of water was fully used in 7 to 17 days in the years 1987 through 1990 and, even during the days of release, it did not provide sufficient flows for adequate fish passage (CBFWA 1990). Monitoring at Lower

Granite Dam indicates that sockeye salmon migrate past this facility between early April and late June, spanning a period of 38 to 73 days (Fish Passage Center 1988; 1989; February 1990). However, the flow at Lower Granite Dam averaged only 77,000 to 88,000 cfs (2,180.4 to 2,491.9 cubic meters per second) during the period (7 to 17 days) of water budget use. This is well below the flow levels identified by the fishery agencies and tribes as needed for passage (CBFWA 1990).

The FWP also does not address the need for flows above the minimum. The fishery representatives had requested a sliding scale that would have made more water available for fish in those years when the annual runoff was greater. This approach was not made part of the water budget. An additional concern is that, in good water years, some of the water budget commitment is made up of increased runoff, and the amount of stored water available for the water budget is subsequently reduced. This results in a water budget that provides water equivalent only to that which would be required during a critically low-flow year.

(ii) Limitation to a 60-day period. The problem with limiting the water budget to a 60-day period is the resulting drop in flows during the subsequent period. Use of water for the water budget in the spring period creates a "hole" in reservoir storage that is then replaced by holding back flows when the water budget request is no longer in force. During these time periods there are still significant numbers of fish passing through the system that are adversely impacted by the low flows

caused by water storage.

(iii) Lack of a Guaranteed Flow. The FWP requires Federal project operators and regulators to "act in good faith" in implementing the water budget as a "firm" requirement to provide 1.19 MAF (1.43 cubic kilometers) at Lower Granite Dam. However, this requirement is subject to the limits of other firm non-power requirements, such as flood control and other authorized purposes of the facilities. In some cases, these criteria conflict with priorities in the FWP. An example of this occurred in 1989 when a water budget request involving Dworshak Reservoir in 1989 was modified by the Corps of Engineers (COE) based on their expressed policy of only providing flow in excess of 85,000 cfs (2,406.95 cubic meters per second) at Lower Granite Dam if it does not affect refill (Fish Passage Center 1990).

In summary, the water budget has the potential to be one of the most important tools available to move juvenile salmon and steelhead downstream past the dams in the Columbia and Snake Rivers. However, its value has been greatly diminished by decisions of the water operating agencies that must also consider the needs of other water users--particularly at those times when it is most critical to fish passage. It is clear that as currently implemented, the water budget is inadequate to prevent the decline of Snake River sockeye salmon stocks.

(2) Juvenile Fish Bypass Facilities. The FWP also addresses juvenile fish mortalities associated with passage through hydroelectric turbines at the mainstem, requiring (1) the

construction of new juvenile fish bypass facilities where none existed; (2) the improvement of existing facilities; and (3) interim fish passage through spill of water at projects without adequate juvenile fish bypass systems. These modifications have been scheduled, but not all schedules have been met. As a result, there are continuing losses of fish.

There are eight mainstem river hydroelectric dams, all operated by the COE, that juvenile Snake River sockeye salmon migrants must pass. Five of these projects have juvenile fish bypasses. Progress on bypass facility installation at the remaining three projects has been slow. Facilities that were to have been completed at Lower Monumental and Ice Harbor Dams in 1989 (NWPPC 1984) are now scheduled for completion in 1992 and 1993, respectively. At the Dalles Dam, the COE now estimates that facilities targeted for 1989 completion in the 1984 FWP will not be completed until 1998. Investigation and implementation of measures to improve the performance of existing systems is an ongoing process.

Passing water over spillways is generally used as an interim measure to protect juvenile downstream migrants until permanent bypass facilities are installed. Fish passing over spillways have substantially higher survival than those going through the turbines (Bell 1976; Heinle and Olson 1981). The proportion of fish passed in spill, however, is directly related to the volume of water spilled. Since spilled water is lost hydropower production, spill is resisted by the project operators as a

passage option. When it is provided, it generally targets only the peak periods of juvenile fish passage.

In 1988, the fishery agencies and tribes entered into a Fish Spill Memorandum of Agreement (MOA) with the Bonneville Power Administration (BPA) that addresses four COE projects where juvenile fish facilities are inadequate or lacking (Spill MOA, 1988, Reprinted in Fish Passage Center, 1989 Annual Report). The COE did not sign the MOA, but in 1989 and 1990 did operate the four projects in accordance with the agreement. The NWPPC adopted the MOA in the 1989 amendments to the FWP (NWPPC, Notice of Final Action on Spill Amendments No. 89-5, February 15, 1989). Spill provided under the MOA at four dams is expected to improve survival of downstream migrants.

(3) Transportation. Collecting fish at an upstream hydroelectric project and transporting them around lower dams and reservoirs for release back into the river are also used to reduce downstream migrant mortalities. Snake River fish are collected and transported from as many as three of the eight COE dams that they must pass. Research has shown that most stocks benefit from such transportation. The effectiveness of transportation is related to inriver flow conditions and the transportation program is most effective when flows are low. There are no data specific to the benefits of transporting Snake River sockeye salmon. Limited studies of transport of Columbia River sockeye salmon were inconclusive because it was not possible to isolate and determine the significance of various

factors that appeared to influence the results, such as the physiological state of fish when transported, the segment of the outmigration during which fish were collected, and differing responses between two Columbia River tributary stocks (Wenatchee River and Okanogan River).

(4) Adult Fish Passage. The FWP also requires the COE to implement adult fishway operating criteria at all COE's projects on the mainstem Columbia and Lower Snake Rivers. Until 1990, these criteria were included in project operations and maintenance plans and separate criteria were provided in a Detailed Fisheries Operating Plan developed by the fishery agencies and tribes. In a revision to the COE's Fish Passage Development and Evaluation Program (see April 19, 1990 letter from Brigadier General Pat M. Stevens, IV), there was agreement on a process for developing a comprehensive, jointly-approved operating plan for both adult and juvenile facilities, but as of this time, a final plan has not been endorsed by all parties.

Beyond agreement on the definition of operating criteria, there is also a question of implementation. As indicated under causes of decline, there have been problems in recent years in keeping facilities in conformance with established criteria. The FWP has not resolved all of the identified adult fish passage problems at Columbia River hydropower facilities.

(5) Integrated System Plan. In 1987, the NWPPC established "doubling runs as a reasonable interim goal." Under the FWP, planning for enhancement activities to meet this goal is to be

based on individual subbasin plans, and an Integrated System Plan to provide a systemwide framework. The plan includes numerous enhancement measures that could be implemented to increase runs. It also states that "improving mainstem migrant survival is the most important strategy, and has the highest priority," and that without these improvements "actions proposed in many of the upriver subbasins will not be successful in increasing the productivity of anadromous fishes."

In summary, there has been some progress on factors contributing to the decline of sockeye salmon under the NWPA and there is potential for even greater improvement. However, the NWPA does not give a priority to salmon and steelhead or provide any regulatory authority to ensure compliance with decisions of the NWPPC. Consequently, despite efforts to date under the NWPA, Snake River sockeye salmon stocks have continued to decline.

5. Other Natural and Manmade Factors.

(a) Natural Factors. Natural factors of greatest concern to Snake River sockeye salmon are periodic droughts and the oceanographic phenomenon known as El Niño. No known landslides causing excessive sedimentation, naturally recurring barriers to salmon migration, or any other impacts to sockeye production have occurred in the Salmon River Basin (personal communication; John Lloyd, Fish Biologist, Sawtooth National Forest).

(1) Droughts. Low water conditions are not as critical for Redfish Lake sockeye spawning and rearing as they are for other species of salmon, since these sockeye spawn and rear in a lake.

However, increased periods of slack water further delay downstream juvenile migrants during drought years. Also, low flows may preclude fish from moving through the dams, particularly those with collection and transport systems. Since agricultural diversions tend to take a fixed amount of water, their impact is more severe during drought years than in other years and adult and juvenile migration are subsequently further impacted.

In the Northwest, annual mean streamflows for the 1977 water year (October - September) were the lowest recorded for many streams since the late nineteenth century (Columbia River Water Management Group 1978). Since 1977, precipitation levels in the Snake River Basin above Ice Harbor Dam were below the 25-year average (1961-1985) in the 1979, 1981, 1985, 1987, 1988, and 1990 water years. The 1990 water year became a fourth consecutive year of drought conditions (Columbia River Water Management Group (in press)).

(2) El Niño. El Niño ocean conditions are characterized by anomalously warm sea surface temperatures, vertical thermal structure, coastal currents and upwelling. Principal ecosystem alterations are decreases in primary and secondary productivity and changes in distributions of prey and predator species. The three most conspicuous El Niño events of recent decades were those of 1940 to 1941, 1957 to 1958, and 1982 to 1983 (Cannon et al. 1985).

The timing and return migration route of mature sockeye

salmon may be influenced by major El Niños that affect large eddies in the northeast Pacific Ocean and the distribution of fish and ocean catches (Mysak 1985). There is no direct evidence that the El Niño events have had an adverse impact on sockeye salmon survival in the ocean.

(b) Manmade Factors. There is no direct evidence that artificially propagated fish have compromised the genetic integrity of Stanley Basin sockeye salmon. Supplementation of kokanee occurred sporadically beginning early in this century. In most cases, the origin of the donor stocks is unknown (Bower, 1990). Preliminary electrophoretic analyses of 19 different sockeye salmon and kokanee samples from Idaho, Washington, and British Columbia (these include the most likely sources for donor stocks for artificially reared smolts) indicated that the Redfish and Alturas Lake kokanee populations are genetically different from the other populations sampled. Sockeye salmon from Redfish Lake were unavailable for sampling. Artificial production of other species may have an adverse impact on sockeye salmon as they jointly migrate through the rivers, estuary and ocean, and may compete with sockeye for food.

Proposed Determination

Based on its assessment of the best scientific and commercial information available, NMFS is issuing a proposed determination that the Snake River sockeye salmon (Oncorhynchus

nerka) is a "species" under the ESA. Furthermore, NMFS proposes to list the Snake River sockeye salmon as endangered under the ESA. Although NMFS determined that an emergency rule is not warranted at this time, NMFS will reconsider if available information indicates that there is an emergency situation posing a significant risk to the Snake River sockeye salmon.

Available Conservation Measures

Conservation measures provided to species listed as endangered or threatened under the ESA include recognition, prohibitions on taking, recovery actions, and Federal agency consultation requirements. Recognition through listing promotes conservation actions by Federal and state agencies and private groups and individuals.

Section 7(a)(4) of the ESA requires that Federal agencies confer with NMFS on any actions likely to jeopardize the continued existence of a species proposed for listing and on actions resulting in destruction or adverse modification of proposed critical habitat. For listed species, section 7(a)(2) requires Federal agencies to ensure that activities they authorize, fund, or conduct are not likely to jeopardize the continued existence of a listed species or to destroy or adversely modify its critical habitat. If a Federal action may adversely affect a listed species or its critical habitat, the responsible Federal agency must enter into formal consultation

with NMFS.

Examples of Federal actions that may be affected by this proposal include authorized purposes of mainstem Columbia River and Snake River hydroelectric and storage projects. Such authorized purposes include hydroelectric power generation, flood control, irrigation, and navigation. Federal actions including COE section 404 permitting activities under the Clean Water Act, COE section 10 permitting activities under the Rivers and Harbors Act, and Federal Energy Regulatory Commission licenses for non-Federal development and operation of hydropower may also be affected.

Based on discussions in this notice, general conservation measures that could be implemented to help conserve the species include the following:

- (1) Adult sockeye returning to the Snake River (Redfish Lake) could be trapped and held for spawning. The progeny would be used to rebuild the sockeye population.

- (2) Efforts could be made to ensure that adult passage facilities at dams effectively pass migrating salmon upstream.

- (3) Flows in the Snake and Columbia Rivers could be regulated to pass downstream migrating fish effectively through the system. It is recognized that coordination of hydropower production in the Northwest is a long-range effort, and major changes in planned river operation cannot be made on short notice. However, NMFS believes that the parties responsible for flow regulation have sufficient authority and flexibility on a

short-term basis to improve passage conditions for sockeye through modification of flow. NMFS will work closely with those parties to monitor water flows during the time the sockeye salmon are in the system.

(4) The catch of sockeye salmon in all Columbia River non-tribal and tribal fisheries could be eliminated. The Oregon Department of Fish and Wildlife and the Washington Department of Fisheries have predicted that returning runs of sockeye salmon in the Columbia River in 1991 will be too low to authorize non-Indian or Indian fisheries. However, under the Columbia River Management Plan, treaty Indian dipnetting remains open and ceremonial and subsistence gillnet fisheries may occur, regardless of sockeye run size.

(5) All water diversions available to downstream migrating juvenile sockeye salmon could be screened. Sockeye salmon juveniles migrate downstream from late April through May. Many unscreened diversions have been identified, and a thorough review of the impact of unscreened diversions on sockeye salmon will be evaluated.

(6) Predators and competitor species in the Stanley Basin lakes could be controlled.

Critical Habitat

Section 4(a)(3)(A) of the ESA requires that, to the extent prudent and determinable, critical habitat be designated

concurrently with the listing of a species. To avoid delaying this listing proposal, NMFS will propose critical habitat in a separate rulemaking.

Public Comments Solicited

To ensure that the final action resulting from this proposal will be as accurate and as effective as possible, NMFS is soliciting comments or suggestions from the public, other concerned governmental agencies, the scientific community, industry, and any other interested parties. Three public hearings have been scheduled (see DATES and ADDRESSES). The final decision on this proposal is due by April 1992 and will take into consideration the comments and any additional information received by NMFS, and such communications may lead to a final action that differs from this proposal.

Classification

The 1982 amendments to the ESA (Pub. L. 97-304) in section 4(b)(1)(A), restricted the information that may be considered when assessing species for listing. Based on this limitation of criteria for a listing decision and the opinion in Pacific Legal Foundation v. Andrus, 657 F.2d 829 (6th Cir., 1981), NMFS has categorically excluded all endangered species listings from environmental assessment requirements of the National Environmental Policy Act (48 FR 4413, February 6, 1984).

The Conference Report on the 1982 amendments to the ESA notes that economic considerations have no relevance to determinations regarding the status of species, and that E.O. 12291 economic analysis requirements, the Regulatory Flexibility Act, and the Paperwork Reduction Act are not applicable to the listing process. Similarly, listing actions are not subject to the requirements of E.O. 12612.

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List of Subjects in 50 CFR Part 222

Administrative practice and procedure, Endangered and threatened wildlife, Exports, Fish, Import, Marine mammals, Reporting and recordkeeping requirements, Transportation.

Date: _____

For the reasons set out in the preamble, 50 CFR part 222 is proposed to be amended as follows:

PART 222 - ENDANGERED FISH OR WILDLIFE

1. The authority citation of part 222 continues to read as follows:

Authority: 16 U.S.C. 1531-1543.

2. In §222.23, paragraph (a) is amended by adding the phrase "Snake River sockeye salmon (Oncorhynchus nerka);" immediately after the phrase "Totoaba (Cynoscion macdonaldi);" in the second sentence.



SALMON RIVER IN IDAHO



CHIEF JOSEPH DAM
ON THE SNAKE RIVER



FISH LADDER
AT
ROCKY REACH



IRRIGATION DIVERSION AND SALMON
SCREEN

"Final" DRAFT

Status Review of Snake River Sockeye Salmon

ESA Biological Review Team
National Marine Fisheries Service
Northwest Fisheries Center
Coastal Zone and Estuarine Studies Division
Seattle, Washington 98112

Predecisional ESA Document--not for distribution

March 4, 1991

NOAA Tech Memo (in press)

Summary

To be considered for protection under the 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.



SUNBEAM DAM, SALMON RIVER, IDAHO

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 Endangered Species Act (ESA). This report summarizes the review of the status of Snake River sockeye salmon conducted by the NMFS Biological Review Team. 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.

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.

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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, with the kokanee generally spawning farther upstream and the 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. 1989a) show that sockeye salmon and kokanee that spawn sympatrically can be very different genetically. Substantial genetic differences were found in spite of occasional cross-spawning behavior of the two forms and viability of hybrids through early life-history stages in culture (Foote et al. 1989b; Wood and Foote 1990). Foote et al. (1989a) 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 et al. (1989a) 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 two systems where they co-occur (Monan 1991).

C. Other studies have shown genetic differentiation between anadromous and nonanadromous forms of brown trout, Atlantic salmon, and steelhead that occur in the same river/lake system (Vuorinen and Berg 1989; Skaala and Naevdal 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. 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).

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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 (IDFG 1920). 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 1921-1934.

D. A diversion tunnel existed for at least part of the period 1910-1934 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 1943-1953.

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 are inherently unreliable. Perceptions of "big" and "little" (e.g., in differentiating sockeye salmon from kokanee) may be distorted by 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 arguments:

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

Counter arguments:

a) It is necessary to postulate a substantial number of strays that fail to home accurately by an enormous distance (over 700 river miles from Redfish Lake to Lake Wenatchee). 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 arguments:

a) 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 arguments:

a) The recent stocking of sockeye salmon eggs is not thought to have produced any returning adult fish (Hall-Griawold 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 occasionally 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 be explained by 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. 1989b; Wood and Foote 1990). If this is so, even poorer performance might be expected from kokanee facing the long migration required for anadromous fish from Redfish Lake.

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

c) 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).

d) In Redfish Lake in recent years, peak spawning for kokanee occurs 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 also 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. 1989b).

c) Although Foote et al. (1989a) 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) demonstrated that 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. 1989a).

b) Kokanee and sockeye salmon spawning in the same lake system often are spatially and/or temporally isolated. Residual sockeye salmon usually attempt to spawn with other sockeye salmon rather than with kokanee.¹

¹(Chris Wood, Canadian Department of Fisheries and Oceans, Nanaimo, British Columbia, personal communication).

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 judgement 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.

Are Snake River Sockeye Salmon an ESU?

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 Species Definition Paper 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) than is Redfish Lake (Dry) (Bailey 1976). 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. 1984; Foote et al. 1989a; 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.

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.

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 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, or if so within what time frame. 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 since the end of the Pleistocene. 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 (ODFW 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.

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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 that 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 from kokanee sampled from the spawning grounds in fall 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 available.

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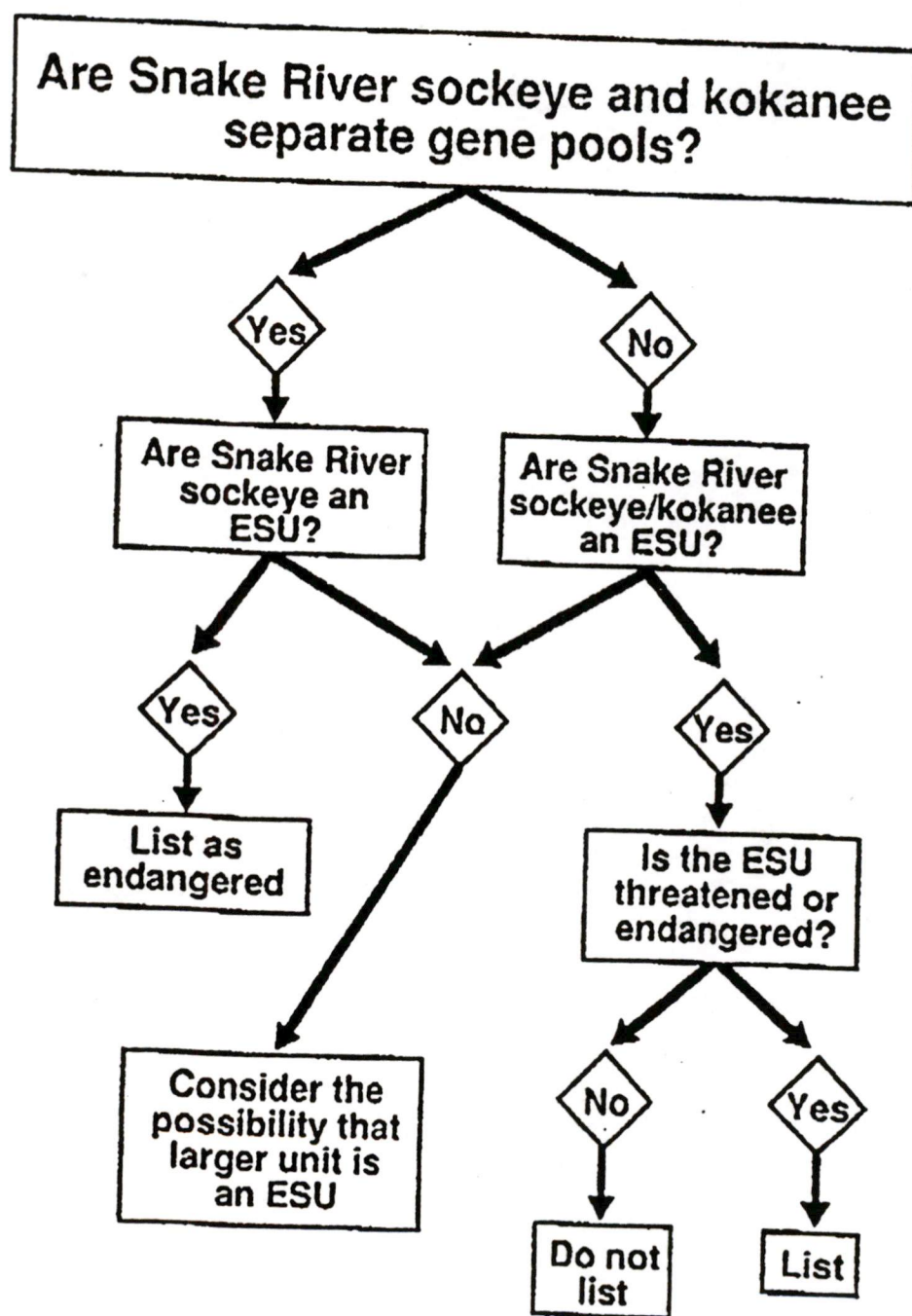


Figure 1.--Decision tree that results from applying the framework of the Species Definition Paper (Waples 1991) to the petition for Snake River sockeye salmon.



SPAWNING KOKANEE
(NON-ANADROMOUS VERSION OF SOCKEYE
SALMON)

**National Oceanic and Atmospheric
Administration**

[Docket No. 910248-1048]

**Interim Policy on Applying the
Definition of Species under the
Endangered Species Act to Pacific
Salmon**

AGENCY: National Marine Fisheries
Service (NMFS), NOAA, Commerce.

ACTION: Notice of interim policy.

SUMMARY: NMFS announces its interim policy on how it will apply the definition of species in the Endangered Species Act of 1973, as amended (ESA) in evaluating Pacific salmon stocks for listing under the ESA. A salmon stock will be considered a distinct population, and hence a species under the ESA, if it represents an evolutionarily significant unit of the biological species. The stock must satisfy two criteria to be considered an evolutionarily significant unit: (1) It must be substantially reproductively isolated from other conspecific population units; and (2) it must represent an important component in the evolutionary legacy of the species. Only Pacific salmon stocks that meet these criteria will be considered by NMFS for listing under the ESA.

DATES: This interim policy takes effect immediately and will be used in evaluating Pacific salmon stocks for listing under the ESA. This interim policy will remain in effect until revised or superseded. Comments on this policy will be accepted until June 11, 1991.

ADDRESSES: Comments should be mailed to the Director, Protected Species Management Division, NMFS, 1335 East-West Highway, Silver Spring, MD 20910.

FOR FURTHER INFORMATION CONTACT: Merritt Tuttle, Environmental and Technical Services Division, NMFS, Portland, OR 97232 (503/230-5401 or FTS/429-5401), or Patricia Montanio, Protected Species Management Division, NMFS, 1335 East-West Highway, Silver Spring, MD 20910 (301/427-2322).

SUPPLEMENTARY INFORMATION:

Background

In addition to an entire species, a distinct population segment of a vertebrate species may be listed and protected under the ESA. On April 2 and June 7, 1990, NMFS received petitions to list a total of five (5) stocks of Pacific salmon under the ESA.

These petitions were all found to present substantial information indicating that the petitioned actions may be warranted and information was requested from the public (55 FR 22942, June 5, 1990; 55 FR 37342, September 11, 1990). The Notices accepting the petitions specifically requested information on whether or not the petitioned stocks qualify as distinct population segments under the ESA.

Both the U.S. Fish and Wildlife Service (FWS) and NMFS, which share jurisdiction under the ESA, have made listing determinations for populations of vertebrate species. Since the Services do not have established criteria for determining what qualifies as a distinct population segment, the Services have made determinations on an *ad hoc* basis based on criteria specific for the species in question. Because of the five pending petitions and numerous other Pacific salmon stocks that in the future may be considered for listing, NMFS developed this interim policy that it will use to determine whether or not a Pacific salmon stock qualifies as a distinct population of vertebrate species. This interim policy does not affect any past listings, such as the listing of the Sacramento River winter-run chinook salmon (final listing determination published November 5, 1990; 55 FR 46515).

Definition of Species

The stated purposes of the ESA are to "provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered species and threatened species" (ESA section 2(b)). A review of legislative history indicates that a major

motivating factor behind the ESA was the desire to preserve genetic variability, both between and within species. For example, the House of Representatives described the rationale for H.R. 37, a forerunner to the ESA, in the following terms (H.R. Rep. No. 412, 93d Cong., 1973):

From the most narrow possible point of view, it is in the best interests of mankind to minimize the losses of genetic variations. The reason is simple: they are potential resources. They are keys to puzzles which we cannot yet solve, and may provide answers to the questions which we have not yet learned to ask.

Under the original 1973 Act, a "species" was defined to include "any subspecies of fish or wildlife or plants and any other group of fish or wildlife of the same species or smaller taxa in common spatial arrangement that interbreed when mature." Use of this language established that the ESA protective measures extend to biological units below the species level. Amendments in 1978 provided the current language in the ESA: A "species" is defined to include "... any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature" (emphasis added).

Congress has provided limited guidance for interpreting this definition. In 1979, Congress declined to enact a provision recommended by the General Accounting Office that would have removed the authority to list vertebrate populations. The Senate Report to the 1979 amendments, however, stated that "the committee is aware of the great potential for abuse of this authority and expects the FWS to use the ability to list populations sparingly and only when biological evidence indicates that such action is warranted" (S. Rep. No. 151, 96th Cong., 1979).

Joint FWS/NMFS regulations concerning the listing process (50 CFR part 424) define "species" to include "any distinct population segment of any vertebrate species that interbreeds when mature" (50 CFR 424.02(k)). In an attempt to develop guidelines for and consistency in interpreting the language of the ESA pertaining to vertebrate populations, FWS and NMFS convened a Vertebrate Population Workshop in June 1990. Workshop participants included scientists with expertise in the fields of genetics and population dynamics. The goal of the workshop was to recommend a consistent approach for determining what qualifies as a distinct vertebrate population. Based, in part, on the results of this workshop, the FWS and NMFS intend to

propose a regulation to further define what constitutes a distinct population segment. Since this proposal will not be published until much later in 1991, NMFS has developed this interim policy to use in listing determinations for Pacific salmon. The interim policy adopted here is consistent with the concepts developed at the workshop.

Because this action is a general statement of policy under 5 U.S.C. 553(b)(A), advanced notice and opportunity for comments are not required; nevertheless, comments on this interim policy are invited, and the policy may be revised through publication in the Federal Register. It will be superseded by any final rule published by the FWS/NMFS to further define "distinct population."

Policy Statement

A stock of Pacific salmon will be considered a distinct population, and hence a species for purposes of listing under the ESA, if it represents an evolutionarily significant unit (ESU) of the biological species. A stock must satisfy two criteria to be considered an ESU:

(1) It must be reproductively isolated from other conspecific population units; and

(2) It must represent an important component in the evolutionary legacy of the species.

The first criterion, reproductive isolation, does not have to be absolute, but it must be strong enough to permit evolutionarily important differences to accrue in different population units. Insights into the extent of reproductive isolation can be provided by movements of tagged fish, recolonization rates of other populations, measurements of genetic differences between populations, and evaluations of the efficacy of natural barriers. Each of these methods has its limitations. Identification of physical barriers to genetic exchange can help define the geographic extent of distinct populations, but reliance on physical features alone can be misleading in the absence of supporting biological information. Physical tags provide information about the movements of individual fish but not the genetic consequences of migration. Furthermore, measurements of current straying or recolonization rates provide no direct information about the magnitude or consistency of such rates in the past. In this respect, electrophoretic (or DNA) differences can be very useful because they reflect levels of gene flow that have occurred over evolutionary time scales. The best strategy is to use all available

lines of evidence for or against reproductive isolation, recognizing the limitations of each and taking advantage of the complementary nature of the different types of information.

The second criterion would be met if the population contributed substantially to the ecological/genetic diversity of the species as a whole. In making this determination, the following questions are relevant:

- Is the population genetically distinct from other conspecific populations?
- Does the population occupy unique habitat?
- Does the population show evidence of unique adaptation to its environment?
- And, if the population became extinct, would this event represent a significant loss to the ecological/genetic diversity of the species?

Several types of information are useful in addressing these questions. Again, the strengths and limitations of the information will be considered in making the evaluation. Phenotypic/life-history traits such as size, fecundity, and age and time of spawning may reflect local adaptations of evolutionary importance, but interpretation of these traits is complicated by their sensitivity to environmental conditions.

Electrophoretic data provide valuable insight into levels of overall genetic differentiation among populations but provide no direct information regarding the extent of adaptive genetic differences. Habitat differences suggest the possibility for local adaptations but do not prove that such adaptations exist.

Technical Paper

In support of this policy, the Northwest Fisheries Center, NMFS, prepared a paper on "Definition of 'species' under the Endangered Species Act: Application to Pacific salmon." This technical paper is available upon request (see FOR FURTHER INFORMATION CONTACT) and contains more specific guidance on the application of this interim policy to Pacific salmon. The paper addresses several issues of particular concern regarding Pacific salmon, including anadromous/non-anadromous population segments, differences in run-timing, stock supplementation, introduced populations, and the role of hatchery fish.

Dated: March 7, 1991.

Michael F. Tullman,

Deputy Assistant Administrator for Fisheries,
National Marine Fisheries Service.

(C. 91-5886 Filed 3-12-91; 8:45 am)

CLASSIFICATION CODE 3510-22-M

DRAFT

**QUESTIONS AND ANSWERS FOR NOAA'S PROPOSED LISTING
OF THE SNAKE RIVER SOCKEYE SALMON AS AN ENDANGERED SPECIES**

QUESTION: What Will NOAA do if it appears that the Snake River sockeye are extinct? Will the agency take conservation measures until it is proven that the species is extinct?

ANSWER: We will not know if Snake River sockeye salmon are extinct until five years after the last redd was observed (1989 + 5 = 1994). Should no fish return by then, the population can be considered extinct. At that time, listing would no longer be appropriate.

The agency will take protective and conservation measures until it is proven that the sockeye population is extinct. If the population is listed as endangered, these measures will include prohibitions on taking, recovery actions, and Federal agency consultation requirements as required under the Endangered Species Act (ESA). Even with a "proposal" to list, NMFS is prepared to take actions in 1991 to capture, preserve and propagate all returning Snake River sockeye. NMFS proposes to build a capture weir at Redfish Lake to receive returning sockeye. They would further construct holding facilities to preserve and protect these fish until they could be spawned and to rear the progeny to maturity.

Even if no sockeye salmon return in 1992, the agency would be prepared to conduct the above efforts through 1994. Because this species has a four to five year life cycle, and there is evidence of sockeye redds (2) in 1989, it is prudent to assume that adult sockeye may return to Redfish Lake through 1994. If there are no sockeye returning by November 1994, the Snake River sockeye may be considered extinct. Both adults and juveniles would be genetically sampled to further aid in species identification.

QUESTION: Why didn't NOAA act sooner? Why isn't the agency using the emergency provisions of the ESA?

ANSWER: The Northwest Region independently initiated a Status Review of Snake River sockeye salmon early in 1990,

DRAFT

prior to receiving the petition. The sockeye population had remained at low but seemingly stable levels until a dramatic decline in the adult fish count at Lower Granite Dam occurred at in the fall of 1989.

Regarding the implementation of emergency provisions of the ESA, the Northwest Region has evaluated those factors that pose adverse impacts to Snake River sockeye salmon and concluded that the immediate promulgation of emergency regulations is unnecessary. However, should over-harvest or adult and juvenile migration issues not be resolved in 1991, emergency listing may be necessary.

QUESTION: Are the salmon fisheries in the Pacific Northwest still in good shape? If so, why? If hatcheries have been successful in maintaining the commercial fisheries, why is the agency protecting wild runs?

ANSWER: In general, the key production stocks (many wild and hatchery populations) are in good condition. However, some of the weaker wild populations have suffered from mixed stock harvest. Wild populations are generally the only populations that qualify for protection under ESA; consequently, hatchery fish can not be regarded as a substitute for petitioned populations. This reasoning stems from one of the purposes of the ESA, which is "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." Thus, self-sustaining populations in the wild are key to achieving this purpose.

QUESTION: Why didn't the Administration propose to fund the Columbia River salmon hatchery in the 92 budget?

ANSWER: The Administration believed that other entities had the responsibility to fund the hatchery program because other entities (hydropower producers) were responsible for the initial declines in salmon abundance.

However, sockeye salmon hatcheries do not exist under the Columbia Fisheries Development Program, which is financed by NMFS. Sockeye hatcheries had generally failed prior to the time when the original Program hatcheries were constructed; consequently, none were built for sockeye. There have been no new hatcheries constructed under this program for several decades.

QUESTION: Will the commercial and recreational salmon fish catch be impacted by listing under ESA?

ANSWER: Yes, if there is a listing the fisheries could be impacted. The recreational salmon catch is negligible, as is the ocean harvest. However, commercial fisheries for sockeye salmon by Indians and non-Indians could be impacted primarily on the mainstem of the Columbia River. Short term forecasts of 1991 abundance of Columbia River sockeye indicate that a fishery is unlikely. Consequently, listing would have little impact that year. There are no forecasts of abundance for subsequent years.

QUESTION: Will NMFS now undertake its own review of all the subspecies of salmon with respect to status of wild salmon stock?

ANSWER: Not in the short term. NMFS will complete the status reviews for the other four stocks of salmon that were petitioned on June 7, 1990. Those reviews are our first priority. Our second priority will be to make a final determination regarding sockeye. NMFS resources are fully committed at this time in completing these tasks.

QUESTION: What is the recovery plan process?

ANSWER: NMFS has an excellent process in place with the Technical Committee (widespread outside membership), the Peer Review group (representatives from academic institutions), and our own scientific staff. In addition, these groups are likely to receive and evaluate information produced by the Hatfield Salmon Summit process. It is our belief that an additional recovery team would simply represent more bureaucracy and would not aid in recovery planning.

UNITED STATES DEPARTMENT OF
COMMERCE
NEWS **DRAFT**
WASHINGTON, D.C. 20230

NATIONAL
OCEANIC AND
ATMOSPHERIC
ADMINISTRATION

NOAA-

NEWS FROM NOAA
(The National Oceanic and Atmospheric Administration)

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NOAA PROPOSES TO
LIST SNAKE RIVER
SOCKEYE SALMON AS
ENDANGERED SPECIES

FOR IMMEDIATE RELEASE

NOAA's National Marine Fisheries Service (NMFS) announced today a proposal to list the sockeye salmon on the Snake River as endangered under the Endangered Species Act (ESA).

A final decision on whether or not to list the stock will be based solely on the best scientific data available on the status of the sockeye, as required under the ESA. Under the ESA, socioeconomic considerations can not affect NOAA's decision whether or not to list. NOAA has up to one year to determine if proposed listing will become final.

During this period between the proposal and any final decision to list, NOAA will employ the participation of others to ensure that the administrative record for the proposal will be accurate and complete. Scientific evaluations and the compilation of data relevant to the sockeye will be solicited from a wide variety of interest groups, conservation organizations, academic and other government and private scientific agencies.

Also under the ESA, any final decision to list will include the preparation of a recovery plan for the sockeye. Although socioeconomic considerations may not affect NOAA's decision to list, incorporation of these factors may be appropriate within the implementation of the recovery plan itself.

In 1990, NMFS initiated a biological status review of the sockeye salmon stock in response to dramatic decreases in run sizes in recent years. Soon after initiating the review, NMFS received a petition to list the stock as endangered from the Shoshone-Bannock Tribes of the Fort Hill Reservation. The proposal to list comes at the completion of the year-long status review.

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Rolland Schmitten, Northwest Regional Director for NMFS, added, "Although some people speculated that the stock is already extinct because none apparently returned from the ocean last year, some year-classes may still be at sea." Due to the four to five to year cycle of spawning for the sockeye, it will not be known whether this species is, in fact, extinct until 1994. Some Snake River sockeye, however, may return over the next three years.

At one time, these fish were so abundant that native Americans and early miners depended on them for food in several locations within the Snake River Basin. Idaho's Redfish Lake's name was derived from the spawning colors of these fish. Last year, no fish were known to have succeeded in reaching the spawning areas, and in the preceding two years, only two redds (salmon nests) were found.

Public hearings on this listing proposal have been scheduled on May 8, 1991, in Seattle, Washington at the NOAA Western Regional Center, 7600 Sand Point Way; on May 9, in Portland, Oregon at the Federal Complex, 911 NE 11th Avenue (1st floor); and May 10 in Boise, Idaho at the Interagency Fire Center, 3905 Vista Avenue. Additional information on hearing schedules may be obtained by calling NMFS at (503) 230-5400.

The proposed listing also allows for a 60-day comment period ending June 2, 1991. Comments may be addressed to:

Endangered Species Coordinator
Environmental and Technical Service Division
National Marine Fisheries Service
911 N.E. 11th Avenue
Suite 620
Portland, OR 97232

In June of last year, four other petitions were received to list additional Columbia River and Snake River salmon species as endangered. Decisions will be made later this year on whether to propose listing these species under the ESA.

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Definition of "Species" Under the Endangered Species Act: Application to Pacific Salmon

by
Robin S. Waples

March 1991

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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DEFINITION OF "SPECIES" UNDER THE ENDANGERED SPECIES ACT:
APPLICATION TO PACIFIC SALMON

by

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Summary

For purposes of the Endangered Species Act (ESA), a "species" is defined to include "any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." Federal agencies charged with carrying out the provisions of the ESA have struggled for over a decade to develop a consistent approach for interpreting the term "distinct population segment." This paper suggests such an approach and explains in some detail how it can be applied to ESA considerations of anadromous Pacific salmonids. The following definition is proposed:

A population (or group of populations) will be considered "distinct" (and hence a "species") for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. A population must satisfy two criteria to be considered an ESU:

- 1) It must be reproductively isolated from other conspecific population units,
and
- 2) It must represent an important component in the evolutionary legacy of the species.

Isolation does not have to be absolute, but it must be strong enough to permit evolutionarily important differences to accrue in different population units. The second criterion would be met if the population contributed substantially to the ecological/genetic diversity of the species as a whole.

Insights into the extent of reproductive isolation can be provided by movements of tagged fish, recolonization rates of other populations, measurements of genetic differences between populations, and evaluations of the efficacy of natural

barriers. Each of these methods has its limitations. Identification of physical barriers to genetic exchange can help define the geographic extent of distinct populations, but reliance on physical features alone can be misleading in the absence of supporting biological information. Physical tags provide information about the movements of individual fish but not the genetic consequences of migration. Furthermore, measurements of current straying or recolonization rates provide no direct information about the magnitude or consistency of such rates in the past. In this respect, electrophoretic (or DNA) differences can be very useful because they reflect levels of gene flow that have occurred over evolutionary time scales. The best strategy is to use all available lines of evidence for or against reproductive isolation, recognizing the limitations of each and taking advantage of the complementary nature of the different types of information.

If available evidence indicates significant reproductive isolation, the next step is to determine whether the population in question is of substantial ecological/genetic importance to the species as a whole. In making this determination, the following questions are relevant:

- Is the population genetically distinct from other conspecific populations?
 - Does the population occupy unique habitat?
 - Does the population show evidence of unique adaptation to its environment?
- and, more generally,
- If the population became extinct, would this event represent a significant loss to the ecological/genetic diversity of the species?

Several types of information are useful in addressing these questions. Again, the strengths and limitations of each should be kept in mind in making the evaluation. Phenotypic/life-history traits such as size, fecundity, and age and time

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of spawning may reflect local adaptations of evolutionary importance, but interpretation of these traits is complicated by their sensitivity to environmental conditions. Electrophoretic data provide valuable insight into levels of overall genetic differentiation among populations but little direct information regarding the extent of adaptive genetic differences. Habitat differences suggest the possibility for local adaptations but do not prove that such adaptations exist.

The framework suggested here provides a focal point for accomplishing the major goal of the Act--to conserve the genetic diversity of species and the ecosystems they inhabit. At the same time, it allows discretion in the listing of populations by requiring that they represent units of real evolutionary significance to the species. Further, this framework provides a means of addressing several issues of particular concern regarding Pacific salmon, including anadromous/non-anadromous population segments, differences in run-timing, supplementation, introduced populations, and the role of hatchery fish.

Introduction

In conjunction with a review of the biological status of Pacific salmon¹ (*Oncorhynchus* spp.) initiated in 1978 by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (FWS), three policy position papers were drafted for the consideration of Columbia River salmon under the Endangered Species Act (the Act; ESA). The draft papers were intended to provide guidance at three critical stages in ESA evaluations: determination of what constitutes a "species" under the Act (and, therefore, may merit protection), determination of thresholds for listing as threatened or endangered, and determination of the role (if any) of artificial propagation in development of recovery plans for listed "species."

On receipt of petitions to list several populations of Pacific salmon as "species" under the Act (April-June 1990), NMFS sought public comments on draft Policy Position Paper #1, "Definition of Species" [a summary of a longer document by Utter (1981)]. The present document is a synthesis of ideas outlined in the previous draft species definition paper, public comments on that paper, and concepts developed over the past decade.

I. Background of the Endangered Species Act

The stated purposes of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*) are to "provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to

¹The term "Pacific salmon" has traditionally referred to species of the genus *Oncorhynchus*, five of which (*O. gorbuscha*, *O. keta*, *O. kisutch*, *O. nerka*, and *O. tshawytscha*) occur in North America. The recent decision to move the western trouts from the genus *Salmo* to *Oncorhynchus* calls this usage into question. In this document, "Pacific salmon" is used to include anadromous forms of *O. clarki* and *O. mykiss*, as well as the five above-mentioned species.

provide a program for the conservation of such endangered species and threatened species." A review of legislative history indicates that a major motivating factor behind the Act was the desire to preserve genetic variability, both between and within species. For example, the House of Representatives described the rationale for House Resolution 37, a forerunner to the Act, in the following terms (H. R. Rep. No. 412, 93d Cong., 1st Sess., 1973):

From the most narrow possible point of view, it is in the best interests of mankind to minimize the losses of genetic variations. The reason is simple: they are potential resources. They are keys to puzzles which we cannot yet solve, and may provide answers to questions which we have not yet learned to ask.

Under the 1973 ESA, a "species" was defined to include "any subspecies of fish or wildlife or plants and any other group of fish or wildlife of the same species or smaller taxa in common spatial arrangement that interbreed when mature." Use of this language established that the scope of the Act extends beyond the traditional biological definition of species to include smaller biological units. Amendments in 1978 [Pub. L. 95-632 (1978), 92 Stat. 3751] provided the current language in the Act: a "species" is defined to include "any subspecies of fish or wildlife or plants, and any **distinct population segment** of any species of vertebrate fish or wildlife which interbreeds when mature" (emphasis added).

Congress has provided limited guidance for interpretation of this definition. Congress declined to enact a provision in the 1979 amendments recommended by the General Accounting Office (GAO)² that would have removed the authority to list vertebrate populations. The Senate Report to the 1979 amendments, however, stated that "the committee is aware of the great potential for abuse of this authority

²GAO, Endangered Species--A Controversial Issue Needing Resolution, Report to Congress (1979).

and expects the FWS to use the ability to list populations sparingly and only when biological evidence indicates that such action is warranted" (S. Rep 151, 96th Cong., 1st Sess., 1979).

In an attempt to develop guidelines for and consistency in interpreting the language of the Act pertaining to vertebrate populations, FWS and NMFS convened a Vertebrate Population Workshop in June 1990. The goal of the workshop was to recommend a consistent approach for determining whether vertebrate populations are "distinct" under the Act. The framework adopted here reflects concepts discussed at the workshop.

Proposed definition: A vertebrate population will be considered distinct (and hence a "species") for purposes of conservation under the Act if the population represents an evolutionarily significant unit³ (ESU) of the biological species. An ESU is a population (or group of populations) that

- 1) is reproductively isolated from other conspecific population units
- and
- 2) represents an important component in the evolutionary legacy of the species.

Note that the dual criteria reflect two common meanings of "distinct": the criterion of reproductive isolation emphasizes the concept of "separate" or "apart from," whereas the criterion of evolutionary importance focuses on characteristics that are "different" or "unique."

³The term "evolutionarily significant unit" apparently originated with Ryder (1986). The usefulness of this concept in the context of ESA evaluations was stressed at the Vertebrate Population Biology Workshop by A. Dizon (NMFS, La Jolla, CA). See Dizon et al. 1991 for additional discussion of this and related concepts.

Isolation does not have to be absolute, but it must be strong enough to allow evolutionarily important differences to accrue in different population units.

Population characteristics that are important in an evolutionary sense must have a genetic basis; therefore, the second criterion would be satisfied if the population in question contributes substantially to the overall genetic diversity of the species.

Because ecological diversity may foster local adaptations (and hence genetic diversity), a population that occupies unique habitat or in other ways represents an important ecological adaptation for the species may also be an ESU.

This framework provides a focal point for accomplishing the major goal of the Act--to conserve the genetic diversity of species and the ecosystems they inhabit. At the same time, it allows discretion in the listing of populations by requiring that they represent units of evolutionary significance to the species. In this framework, reproductive isolation is a necessary but not a sufficient condition for a population to be considered "distinct." Presumably, given enough time, an isolate will evolve into an ESU, but isolation by itself does not confer distinctness. For example, a population recently isolated as the result of human activity probably does not play an integral role in maintaining ecological or genetic diversity of the species. The same might be true for some natural isolates, particularly those of recent origin.

II. Application to Pacific Salmon

Application of the ESU concept to Pacific salmon requires consideration of reproductive isolation and ecological/genetic diversity. For convenience these concepts are considered separately here, but it is recognized that they are inherently related.

A. Reproductive isolation⁴

With Pacific salmon, reproductive isolation is seldom a black-and-white situation; rather, it is a question of degree (e.g., Ricker 1972). Although the homing instinct is well documented in these species, natural straying does occur, and anadromous⁵ spawning populations that are completely isolated from other conspecific populations are probably rare. A relevant question thus becomes, How much exchange with other populations can a salmon population experience and still be considered an ESU? Similarly, it is important to consider whether isolation is a recent phenomenon or whether it represents a long-standing condition.

One approach to this question emphasizes the effects of migration in inhibiting genetic differentiation. The term "gene flow" is commonly used to describe the movement of genes from one population to another; that is, gene flow represents genetically effective migration. An oft-cited maxim based on Sewall Wright's work is that gene flow between populations at the rate of one individual per generation is sufficient to prevent the tendency for different alleles to be fixed by chance (genetic drift) in different populations. Migration (the physical movement of individuals) may occur at a higher rate than gene flow if some migrating individuals fail to reproduce or do not produce viable offspring.

Although gene flow at the level of one individual per generation may prevent extreme genetic divergence, it is not sufficient to equalize allele frequencies across populations, and Wright (1978) also pointed out that genetic differentiation is by no means negligible even if gene flow occurs at several times this rate. Furthermore,

⁴This discussion of reproductive isolation focuses on the degree to which a population is isolated from genetic contact with other natural populations. Straying from hatchery stocks and intentional transfers of fish from one area to another are discussed in Section III-C.

⁵Non-anadromous populations or segments of populations are considered in Section III-A.

the above comments apply to a balance between migration and genetic drift of neutral alleles. If there is local adaptation for different alleles in different populations, the homogenizing effects of migration will be counteracted somewhat by different selective regimes, thus allowing greater differences among populations to be maintained.

Another way to consider the migration problem is to view it as a question of replacement. In this context, the relevant question is, If all individuals in the population in question were permanently removed, would the area naturally be repopulated by individuals of the same biological species, and if so, within what time frame? Presumably, an area that would be repopulated at or near the previous abundance level in a short time would be unlikely to harbor an ESU. This will be a largely theoretical exercise for populations being considered for protection under the Act. However, some insight can be gained from observations of recolonization rates in other populations and/or species.

The level of migration or gene flow occurring among populations can be evaluated in several ways. Approaches that may prove useful for Pacific salmon include:

- 1) Use of tags to estimate straying rates;
- 2) Intentional genetic marking of populations;
- 3) Use of genetic indices [e.g., Wright's (1978) F_{ST} or Slatkin's (1985) private allele method] to estimate levels of gene flow;
- 4) Observations of recolonization rates;
- 5) Identification of physical or geographic features likely to act as barriers to migration.

Since the 1950s, extensive data bases have been developed that provide important information about the oceanic distribution of Pacific salmon (e.g., Hartt 1962).⁶ More recently, physical tags have been used to study migrations of fish from individual populations. However, tagging efforts typically focus on hatchery stocks, and much less is known about straying in natural populations. Furthermore, such studies do not provide direct evidence of gene flow. A salmon may swim into a nearby stream (and perhaps be counted as a stray) before ultimately making its way to its natal stream to spawn. Reproductive success of strays may also be less than that of fish from the local population.

A direct measurement of gene flow can be obtained by monitoring changes over time in the frequency of genetic markers characteristic of different populations. Because Pacific salmon populations are typically characterized by different frequencies of the same suite of alleles, rather than by qualitative differences in the types of alleles present, it often will be difficult to measure gene flow precisely without enhancing the frequencies of different alleles in different populations (intentional genetic marking). Although the few genetic marking studies that have been conducted with Pacific salmon (e.g., Seeb et al. 1986; Lane et al. in press) have provided important information, opportunities for such studies involving populations that are potential candidates for ESA listing are likely to be limited.

An indirect measurement of gene flow is provided by Wright's and Slatkin's methods, which measure some of the genetic consequences of migration. Accuracy of such estimates depends on the degree to which the various assumptions of the models used are satisfied. Notably, both methods assume selective neutrality of the alleles used, and results may be sensitive to the geographic configuration of the study sites included. Both methods are also based on equilibrium models and may

⁶See also subsequent INPFC Bulletins on salmon distribution.

overestimate migration rates if not enough time has elapsed to obtain a balance between the forces of migration and genetic drift.

Opportunities to observe recolonization are not common with Pacific salmon, but they do occur. Aspinwall (1974) described one experiment that eradicated an entire run of pink salmon to study straying. Natural events (e.g., the eruption of Mount St. Helens) sporadically occur that cause extinction of populations or allow access to previously blocked habitat. In evaluating the results of such "experiments," it should be recognized that if intraspecific interactions (e.g., competition) are acting to hinder the success of migrants or strays, recolonization of empty habitat may occur at a higher rate than expected from migration rates among fully-seeded populations.

Because natural straying in Pacific salmon seems to be largely confined to nearby areas, geographic proximity (e.g., linear stream distance) of a population from other conspecific populations can provide a useful approximation of the degree of reproductive isolation. A number of studies of Pacific salmon have found genetic clustering of populations to occur largely along geographic lines. However, exceptions to this pattern have also been found, which emphasize the fact that distance is not the only barrier to gene flow. Consideration should also be given to other factors (e.g., geological history and physical and environmental gradients) that can affect population structuring.

As can be seen from this brief discussion, each of the above approaches has some limitations. Nevertheless, it is important to consider all available information because the various approaches provide different insights into the question of reproductive isolation. Recolonization rates provide the most direct indication of the likelihood that a population, if eliminated, would become reestablished naturally. Approaches 1, 2, and 4 can provide data on current levels of migration or gene flow

(over periods of one or a few generations). It is unlikely, however, that migration rates have been constant over long periods of time. In some cases, significant gene flow may occur only at intervals of decades or centuries. Wright's and Slatkin's methods can be very informative in this context because these indices reflect the cumulative effects of gene flow over evolutionary time scales.

B. Ecological/genetic diversity

If available evidence indicates significant reproductive isolation, the next step is to determine whether the population in question is of substantial ecological/genetic importance to the species as a whole. Because of the emphasis in the Act on conserving native ecosystems, ESA considerations of Pacific salmon should focus on naturally-spawning fish. In determining whether a wild⁷ population is an ESU, it is sufficient to demonstrate that the population in question is "distinct" from other wild populations. Relevant questions to ask in this context are

- Is the population genetically distinct from other conspecific populations?
- Does the population occupy unique habitat?
- Does the population show evidence of unique adaptation to its environment?

and, more generally,

- If the population became extinct, would this event represent a significant loss to the ecological/genetic diversity of the species?

Factors that are important to consider in addressing these questions include (but are not necessarily limited to) the following:

⁷Wild fish in this usage includes all fish that are the progeny of naturally-spawning fish.

- 1) Genetic traits. Examples include characters detected by protein electrophoresis or DNA analyses.
- 2) Phenotypic traits. Examples include morphological and meristic characters, occurrence of parasites, and disease resistance.
- 3) Life-history traits. Examples include time, size, and age at spawning; spawning behavior; fecundity; migration patterns; and timing of emergence and outmigration.
- 4) Habitat characteristics. This category includes such physical characteristics of the spawning and rearing habitat as temperature, rainfall, stream flow, and water chemistry, as well as biological attributes of the local ecosystem. In a broader sense, the habitat for a population also includes areas encountered during the entire life cycle. Thus, a waterfall in the migratory route might select for robust fish capable of surmounting it, and a population with distinctive oceanic migration patterns probably utilizes distinct marine habitat.

Two points are important to consider in evaluating these data. First, such data can be properly evaluated only in relation to similar information for the species as a whole. That is, some reference data are essential before one can determine that a particular population is distinct.

Second, it is unlikely that all relevant information will be available for any given ESA evaluation. This is particularly true for status reviews that must be conducted within a limited time period in response to formal petitions to list. ESA determinations must be made on the basis of the best available scientific information, and all types of data (including genetic, phenotypic, and life-history traits and habitat characteristics) should be considered.

Data from protein electrophoresis or DNA analyses permit direct inferences about genetic divergence and thus are particularly applicable to the question of population distinctness under the Act. However, if the common presumption is correct that the genetic characters detected by these methods are largely neutral with respect to natural selection, then it follows that differences among populations in these characters do not by themselves denote evolutionary significance (except in the sense that neutral genes may provide the raw material for future evolution). Rather, these genetic characters are primarily useful as indicators (or proxies) for evolutionary processes that can lead to local adaptation in other parts of the genome more directly related to fitness.

Several types of genetic analyses can provide information relevant to ESA considerations. Gene diversity analysis can be used to partition the total genetic variance in a species in a variety of ways, including between-population, within-population, and between-years (within population) components. Results can be compared with data for other species (and other salmonids in particular) to provide insight into the degree of genetic distinctness of the population under consideration. Genetic distance indices can be used in a similar fashion, and comparisons of heterozygosity levels may also be informative in some cases.

Phenotypic and life history traits may reflect local adaptations, and for this reason they may be relevant to the evaluation of population distinctness. However, expression of these traits is known to be affected by environmental as well as genetic factors, which complicates their interpretation.

Analysis of habitat characteristics is important in two ways. First, the existence of unique habitat features allows for the possibility of unique adaptations in the local population. Second, identification of unique habitat is one step toward

achieving the broad purpose of the Act--to preserve threatened and endangered "species" and the ecosystems they inhabit.

C. Recommended approach

The following approach is suggested for making a determination regarding population distinctness under the Act.

1) Evaluate the degree of reproductive isolation. If there is gene flow with other populations, it should be at a level low enough to permit evolutionarily important divergence. If apparent migration rates with adjacent populations are high, the population would not be considered isolated unless there is evidence that the genetically effective migration rate is much lower. Approaches outlined in Section A should be used to address the questions of migration rate, gene flow, and recolonization rate.

If the population is believed to be reproductively isolated, an evaluation under Step 2 (below) should be made; if it is not isolated, the population is not an ESU and should not be considered for listing under the Act.

2) Evaluate evidence for ecological/genetic distinctness in the context of similar data from throughout the species range, as well as for other species as appropriate. Often, this process will involve difficult judgments concerning the relative importance to attach to different types of evidence. Although a variety of approaches may prove useful in making this determination, none will provide a completely objective assessment of evolutionary significance. Nevertheless, some general guidelines can be suggested to aid the evaluation process.

The existence of substantial electrophoretic or DNA differences from other conspecific populations would strongly suggest that evolutionarily important,

adaptive differences also exist. The failure to find electrophoretic or DNA differences (or the absence of genetic data) would not rule out the possibility that such adaptive differences exist, but it would place a greater burden of proof on data for other characters.⁸ Data for habitat characteristics should be interpreted in a similar fashion: habitat differences suggest (but do not prove) the possibility of adaptive differences, whereas the inability to detect habitat differences constrains the scope of possible local adaptations but does not prove they do not exist. In evaluating data for phenotypic and life-history traits, every effort should be made to account for environmental effects that are manifested in periods shorter than one generation (and therefore do not reflect adaptations).

III. Special Considerations

A. Anadromy/nonanadromy

Some species of Pacific salmon (*Oncorhynchus nerka*, *O. mykiss*, and *O. clarki*) have nonanadromous as well as anadromous forms that occur together. A similar phenomenon occurs in some species of the genera *Salmo* and *Salvelinus*. This raises the question whether the two forms should be considered jointly or separately in deciding if a population is "distinct" under the Act. The following general guidelines are suggested.

The two forms should be considered separately if they are reproductively isolated. As noted above, the question of reproductive isolation is likely to be one of degree. Again, the key question is whether isolation is strong enough for

⁸Although "electrophoretic and DNA" techniques are considered here together for convenience, there are a variety of parts of the nuclear or mitochondrial genome that can be targeted for study. It is important to realize that the sensitivity of the different approaches can vary considerably, and this factor must be considered in interpreting the results of genetic analyses.

evolutionarily important differences to develop in the two forms. Genetic data can be valuable in making this determination, as can observations of general spawning behavior, including time and place of spawning. Information from other populations (and other species) can help provide a context for making the evaluation. However, such studies have shown that a wide variety of scenarios probably exists in nature (from substantial reproductive isolation of sympatric anadromous and nonanadromous forms to substantial life-history plasticity within presumably a single gene pool). Therefore, such studies are unlikely to provide an unequivocal answer for an unstudied anadromous/nonanadromous system.

If substantial gene flow occurs or has recently occurred between the two forms, they represent polymorphisms of a single population and should be considered as a unit for purposes of the Act. In determining whether such a population unit is an ESU, the anadromous and nonanadromous traits should be considered in the same manner as other population characteristics discussed in Section II-B. That is, the important questions are whether the traits have a genetic basis and whether they help to make the population unit "distinct" from other populations. For example, an anadromous/nonanadromous unit might be considered an ESU if all ecologically comparable populations of the species harbored only the nonanadromous form. In this case, if the population unit is considered to be an ESU solely or primarily on the basis of the anadromous trait, then the potential loss of anadromy should be a legitimate ESA concern. Therefore, an anadromous/nonanadromous population unit could be listed based on a threat to one of the life-history traits, if loss of that trait would compromise the "distinctness" of the population.

B. Differences in run-time

In several species of Pacific salmon, biologists recognize different run-times, or races, of fish inhabiting the same general area. Generally, run-times are determined on the basis of the time of year at which adults enter fresh water to spawn. The question whether such races represent "distinct" populations under the Act can be addressed in the framework developed above.

First, it should be determined whether the different run-times are reproductively isolated. Often, the distinction between spring- and summer-run (for example) is fairly arbitrary, with fish appearing before a certain date classified as "springs" and those appearing after that date as "summers." In such cases, and in the absence of a discrete distribution of run-times, additional evidence (for example, time and place of spawning) needs to be developed to establish reproductive isolation.

Assuming that fish with different run-times are reproductively isolated, they can be considered to comprise distinct populations under the Act if they exhibit evolutionarily important ecological/genetic differences, as outlined in Section II-B above. In the absence of substantial isolation between run-times, a "population" unit consisting of two or more recognized run-times could be considered an ESU if it were isolated from and distinct from other populations.

C. Effects of supplementation and other human activities

Supplementation (or overplanting) is the release of hatchery-reared fish into a wild area occupied by native fish of the same biological species. The effects of supplementation are relevant to the question of population distinctness because a population that has been overplanted with fish of different origin may not be an

ESU even if it once was distinct. However, evidence merely of the release of exogenous fish is not sufficient to disqualify a population from consideration as an ESU. In making that determination, two factors should be considered. It is assumed that the population in question was distinct enough to be an ESU prior to contact with exogenous fish.

First, supplementation (or straying from hatcheries) has a direct genetic effect only if the transplanted fish successfully reproduce and contribute to subsequent generations of the native stock. Results of supplementation efforts with Pacific salmon have been quite variable (Ricker 1972) and at present are largely unpredictable. For example, a recent review (Hindar et al. in press) cited examples in which the native stock had been largely or entirely displaced, examples of hybridization between native and hatchery fish, and examples in which repeated hatchery releases had no detectable genetic effect on the native population. Therefore, it should not automatically be assumed that transplantation efforts have permanently altered the genetic structure of native populations.

Second, a population that does not represent a completely pure native gene pool may still qualify as an ESU if it is adapted to its local environment and is "distinct" by the criteria outlined in Section II-B. This point is important for Pacific salmon, because there are relatively few populations for which the possibility of some genetic influence from transplants or hatchery strays can be completely excluded. How much introgression from other gene pools must occur before a population no longer merits consideration as an ESU depends on the degree of distinctness of the original population. The key question to consider is whether stock mixing has compromised the evolutionarily important adaptations that distinguished the original population.

In evaluating the effects of supplementation on native gene pools, the following types of information should be gathered whenever possible:

- 1) Genetic, phenotypic, and life history traits and habitat characteristics for the transferred stock;
- 2) Brood-stock and rearing protocols for the transferred stock;
- 3) Dates of release, number released, and developmental stage at release;
- 4) Trends in abundance of the local population for a time span bracketing the time(s) of release;
- 5) Evidence for reproductive success of transplanted fish, including evidence for incorporation of foreign genes into the local population.

Other human activities (e.g., fishing, pollution, and artificial propagation) can also affect the genetic structure of native populations, and the importance of these factors to ESA considerations can be evaluated in a similar way. Again, the relevant question is whether the activities have changed the population so much that it no longer represents an evolutionarily significant component of the biological species.

D. Hatchery fish

Hatchery fish may enter into ESA considerations in several ways. For example, the effects of supplementation and straying by hatchery fish should be considered in evaluating whether a wild population is an ESU. Artificial propagation may also play a role in recovery plans for some "species." However, fish hatcheries do not provide a substitute for natural ecosystems that the Act mandates the Department to conserve. The role of artificial propagation under the

Act is to restore populations in natural habitat to the point where they can be removed from formal ESA protection. Therefore, only naturally-spawning populations should be considered in determining whether a population is distinct for the purposes of the Act.

An exception to the rule that an ESU must correspond to a wild stock may be made for a hatchery population that represents the only remaining component of a native gene pool. In that case, the hatchery population could be determined to be an ESU if it met the criteria set out in Section II.

E. Historic population size

For a population that once was abundant but since has declined in numbers, there should be no minimum size for ESA consideration. However, populations may also be small because of limiting physical or biological factors. For Pacific salmon, suitable habitat may severely limit the potential number of spawners and hence the carrying capacity of small streams. Given the large temporal fluctuations in abundance documented for every species (and many populations) of Pacific salmon, and given the likelihood that even greater fluctuations have occurred over evolutionary time, there must be some size below which a spawning population is unlikely to persist in isolation for a long period of time. The fact that small spawning aggregations are regularly observed may reflect a dynamic process of extinction, straying, and recolonization. Such small populations are unlikely to be ESUs, although a collection of them might be. Therefore, the historic size of a population may be useful in evaluating whether it is an ESU.

Both genetic and demographic factors should be considered in making this evaluation. Although there is no consensus among geneticists regarding the

minimum effective population size per generation (N_e) necessary to avoid long-term problems of inbreeding and loss of genetic variability, most estimates are in the range of several hundred.⁹ For a species with average age at spawning of 3-5 years (typical of many populations of steelhead and chinook, chum, and sockeye salmon), this would correspond to an effective number of breeders per year (N_b) of perhaps 50-100.¹⁰ Because not all individuals successfully spawn, and because the variance among individuals in reproductive success may be high, the total number of adults must generally be somewhat more than this (perhaps several times as many).

The long-term persistence of an isolated population also depends on its ability to withstand inevitable (and often large) fluctuations in abundance caused by the interplay of population dynamics, changing environmental conditions, and chance events. The importance of these factors varies among species and among populations within species and must be evaluated on a case-by-case basis. In general, however, such fluctuations may place greater constraints on the long-term survival of small populations than do genetic factors associated with inbreeding.

A Pacific salmon population should not be considered an ESU if the historic size (or historic carrying capacity) is too small for it to be plausible to assume the population has remained isolated over an evolutionarily important time period. In making this evaluation, the possibility should be considered that small populations observed at present are still in existence precisely because they have evolved mechanisms for persisting at low abundance. Population genetics theory indicates that gradual inbreeding over a period of time may purge deleterious, recessive alleles from a population, lessening the effects of inbreeding depression and allowing

⁹See discussions by Lande and Barrowclough (1987) and Simberloff (1988).

¹⁰For a discussion of the rate of loss of genetic variability in Pacific salmon and the relationship between N_e and N_b , see Waples (1990).

a smaller effective size than would ordinarily be the case. It is possible that, in some populations, a similar process--evolution of demographic parameters, for example--may have occurred that modulates the effects of environmental variability. Because such populations would contain adaptations that might truly be considered to be of evolutionary significance to the species, and because small populations in general are a likely source of evolutionary innovation, it is prudent to exercise caution in eliminating a population from ESA consideration simply on the basis of historic size. Nevertheless, this concept should prove useful in focusing attention on populations with the greatest probability of representing ESUs.¹¹

F. Groups of populations

Geographical considerations often suggest a natural hierarchical structure for Pacific salmon populations: large river systems may contain several drainages, and each drainage may have major tributaries with smaller streams that support spawning aggregations. Determining the appropriate level for consideration as an ESU is a challenging task. Although the strong homing instinct of these species indicates that even small spawning aggregations may in some sense represent biological populations, such populations may not meet the criteria to be considered "distinct" under the Act. A group of populations, however, might be distinct from, and isolated from, other groups of populations. Such a group of populations can constitute an ESU, and, if determined to be threatened or endangered, can be afforded protection under the Act.

¹¹This concept is related to, but differs from, the concept of minimum viable population size (MVP). The MVP concept considers the future and asks how large a population must be to have an acceptably high probability of surviving a specified period of time. The historic population size concept considers the past and asks how small a population must be before it becomes unreasonable to assume it has persisted in isolation long enough for important adaptations to evolve.

In evaluating the appropriate grouping level, a balance must be struck between two opposing concerns. On the one hand, it is important to identify the smallest units that meet the criteria set out in Section II, because this allows the greatest flexibility in ensuring the appropriate level of protection for different ESUs within a more comprehensive group. On the other hand, we have seen in Section III-E (above) that the smallest units supporting local populations of salmon may not be evolutionarily independent from other nearby populations. A key question is, How can evolutionarily important units be protected without running the risk of artificially maintaining units that might naturally undergo episodes of extinction/recolonization on something short of evolutionary time scales?

The following approach is suggested. Identifiable ESUs should not be combined for the sake of convenience. In general, however, ESUs should correspond to more comprehensive units unless there is clear evidence that evolutionarily important differences exist between smaller population segments. This approach is consistent with the stipulation that NMFS and FWS should use sparingly their authority to list vertebrate populations. Nevertheless, it is recognized that the long-term viability of a larger unit may also depend on the continued existence of multiple, semi-independent units it comprises. Recovery plans for listed "species" could take this into account by ensuring protection for smaller units within a more comprehensive ESU. This might be appropriate, for example, if the smaller units differ in various characteristics but it is uncertain how these differences relate to evolutionary significance.

G. Introduced populations

In general, populations resulting from the introduction of fish into a local area not occupied by the biological species (particularly if the area is outside the historic range of the species) are probably not ESUs because they do not contribute to maintaining diversity of the species in its native habitats. Some introduced populations should **not** be excluded from ESA consideration, and these include populations occupying habitat that is ecologically similar and geographically proximate to the source population, and those that represent the only remaining component of a native gene pool. In the former case, the introduced population may be determined to be part of the same ESU as the parent population; in the latter case, the population could be determined to be an ESU if it met the criteria outlined in Section II.

H. Interpreting results of statistical tests

1. Sampling considerations

Rigorous analyses of data used in ESA considerations will include testing hypotheses whenever possible, and sampling protocols are important to consider in this context. In general, regardless of the characters being considered, the appropriate null hypothesis to test is that no differences exist between the populations being compared. Sampling from the populations introduces a source of random error with magnitude inversely proportional to sample size. In many statistical tests, the implicit assumption behind the null hypothesis is that the samples being compared were drawn from the same population. There are several ways in which this basic assumption might be violated by the method of sampling, and the effects of violating the assumption are often magnified in small populations

(as may frequently be encountered in ESA evaluations). Furthermore, the unusual life history features of Pacific salmon (e.g., the combination of semelparity with overlapping age classes) provide some additional opportunities for sampling bias. These factors should be kept in mind in designing sampling plans and in evaluating results.

a. Temporal changes within populations. Although most Pacific salmon spend the majority of their life at sea, they exist in recognizably discrete populations only during rearing as juveniles and spawning as adults. By necessity, samples are generally taken from local spawning populations, and often only a single brood year is sampled. It must be realized that the population as a whole includes several brood years, and values for a given character will show year-to-year variation around the mean for the population as a whole. The effects of temporal variation within a population must be considered in comparing single-brood-year samples from different populations; in general, this factor will inflate the observed level of difference above that predicted by the null hypothesis, even if the overall population means do not differ.¹² A study plan that involves temporally-spaced samples within sites as well as samples from geographically distinct localities is the best way to evaluate the significance and stability of between-population differences.

b. Life history stage sampled. Waples and Teel (1990) showed that, in comparing two (or more) samples, the probability of a statistically significant result may depend on the life history stage sampled. In general, sampling juveniles will tend to produce larger differences than sampling adults. This will be a minor effect if the sample size is small relative to the population size, but this may not always be true for populations under ESA consideration.

¹²See discussion of a similar point in Waples (1989) and Waples and Teel (1990).

c. Non-representative sampling. Most statistical tests assume random sampling, which means that every individual in the population(s) has an equal opportunity to appear in the sample. There are several ways in which this condition might not be met with Pacific salmon. For example, adults may be sampled only during part of the spawning run, or only in limited areas of a stream. Under certain circumstances, samples of juveniles may include large numbers of individuals from the same family. Methods for sampling either life history stage may select for certain types of individuals.

2. Significance of results

It is important to realize that "statistical significance" is a different concept than "evolutionary significance" as it relates to the Act. In the present context, a statistically significant result indicates that the means for a pair or group of samples differ by more than would reasonably be expected if a single population were sampled repeatedly. The conclusion would be that the population means are different for the character under consideration. Being "different," however, is not the same as being "distinct" under the Act. For a population to be considered an ESU, it must differ from other populations in an evolutionarily important way. Statistical tests can be useful in making this determination but do not in themselves provide direct evidence regarding evolutionary significance. Similarly, failure to find a statistically significant difference does not disprove the existence of population differences. Power to detect true differences in population means is a function of sample size, so this factor should also be considered in evaluating results of statistical tests.

IV. General Comments

This paper presents a simple, flexible framework for interpreting language in the Endangered Species Act pertaining to vertebrate populations: simple because a pair of criteria can be applied to determine whether a population segment is distinct and hence a "species" for purposes of the Act, and flexible because the two criteria can be used to address a variety of issues of particular concern for Pacific salmon.

By focusing on evolutionary significance, the ESU concept also provides a means of dealing with several recurring problems posed by the term "distinct population segment." For example, in 1979 the GAO pointed out potential abuses in the authority to list vertebrate populations, suggesting that this could lead to absurdities such as the listing of squirrels in a specific city park.¹³ Such a result is unlikely under the present framework. Although squirrels in a park might at present be effectively isolated from squirrels in other parks or natural habitat, such a population would be unlikely to meet the second criterion for an ESU (evolutionary significance). Similarly, a population unit artificially isolated as a result of human activities (e.g., by the construction of a dam) probably also does not meet the second criterion, although it might eventually become an ESU if the isolation were to persist for a long enough period of time.

It will have been noted by many that although this paper establishes a framework for considering populations of Pacific salmon under the Act and provides guidance for its application, it does not provide a simple formula for determining whether the unit under consideration is a "species." To the extent that the process would be simpler and more objective with such a formula, the approach adopted here is a disadvantage. However, use of a simple (or even a complex) formula does

¹³GAO, Endangered Species--A Controversial Issue Needing Resolution, Report to Congress (1979).

not seem consistent with the stipulation of the Act [Sec. 4(b)(1)(A)] to make decisions "solely on the basis of the best scientific and commercial data available." The process of evolution and differentiation within and between species is manifest in so many different ways that no simple yardstick will be universally applicable. This does not necessarily mean that more definitive guidelines for making species determinations under the ESA are not possible. It is hoped that public comment and discussion of ideas presented here will help to focus attention on those characteristics thought to be most important in defining "distinct population segments" of Pacific salmon.

Acknowledgments

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