Preliminary conclusions regarding the updated status of listed ESUs of West Coast salmon and steelhead

D. Sockeye salmon

February 2003

Co-manager review draft

This section deals specifically with sockeye salmon. It is part of a larger report, the remaining sections of which can be accessed from the same website used to access this section (http://www.nwfsc.noaa.gov/). The main body of the report (Background and Introduction) contains background information and a description of the methods used in the risk analyses.

D. SOCKEYE

D.1 BACKGROUND AND HISTORY OF LISTINGS

Spawning populations of sockeye salmon, *Oncorhynchus nerka* range from the Columbia River in the south to the Noatak River in the north in North America, and from Hokkaido, Japan in the south to the Anadyr River in the north in Asia (Atkinson et al. 1967, Burgner 1991). The vast majority of sockeye salmon spawn in either inlet or outlet streams of lakes or in lakes themselves. The offspring of these "lake-type" sockeye salmon utilize lake environments for juvenile rearing for 1 to 3 years and then migrate to sea, returning to the natal lake system to spawn after spending 1 to 4 years in the ocean. However, some populations of sockeye salmon spawn in rivers without juvenile lake rearing habitat. The offspring of these riverine spawners utilize slow-velocity sections of rivers as juvenile rearing habitat for 1 or 2 years ("river-type" sockeye salmon), or migrate to sea as underyearlings and therefore, rear primarily in saltwater ("sea-type" sockeye salmon) (Wood 1995). In common with lake-type sockeye salmon, river/sea-type sockeye salmon return to natal spawning habitat after 1 to 4 years in the ocean.

Certain self-perpetuating, nonanadromous populations of *O. nerka* that become resident in lake environments over long periods of time are called kokanee in North America. Genetic differentiation among sockeye salmon and kokanee populations indicates that kokanee are polyphyletic, having arisen from sockeye salmon on multiple independent occasions, and that kokanee may occur sympatrically or allopatrically with sockeye salmon. Numerous studies (reviewed in Gustafson et al. 1997) indicate that sockeye salmon and kokanee exhibit a suite of heritable differences in morphology, early development rate, seawater adaptability, growth and maturation that appear to be divergent adaptations that have arisen from different selective regimes associated with anadromous vs. nonanadromous life histories. These studies also provide evidence that sympatric populations of sockeye salmon and kokanee can be both genetically distinct and reproductively isolated (see citations in Gustafson et al. 1997). Occasionally, a proportion of juveniles in an anadromous sockeye population will remain in the rearing lake environment throughout life and will be observed on the spawning grounds together with their anadromous siblings. Ricker (1938) first used the terms "residual sockeye" and "residuals" to refer to these resident, non-migratory progeny of anadromous sockeye salmon.

In April 1990, NMFS initiated a status review of sockeye salmon in the Salmon River Basin and received a petition from the Shoshone-Bannock Tribes of the Fort Hall Indian Reservation to list Snake River sockeye salmon as endangered under the ESA (NMFS 1990, 1991a). The NMFS Biological Review Team conducted a status review and unanimously agreed that there was insufficient information available to determine with reasonable degree of certainty the origin of the current sockeye salmon gene pool in Redfish Lake (Waples et al. 1991). After some discussion, the BRT reached a strong consensus that, in this instance, obligations as resource stewards required them to proceed under the assumption that recent sockeye salmon in Redfish Lake were descended from the original sockeye salmon gene pool. Therefore, as stipulated in the Species Definition Paper (Waples 1991), the anadromous component of *O. nerka* was considered separately from the non-anadromous (kokanee) component in determining whether an ESA listing was warranted. The decision to treat Redfish Lake sockeye salmon as distinct from kokanee led the BRT to conclude that the Redfish Lake sockeye salmon were in danger of extinction (Waples et al. 1991). Subsequently, a proposed rule to list Snake River sockeye salmon as endangered was published (NMFS 1991a). After consideration of 183 written comments and testimony from public hearings, NMFS published its final listing determination (NMFS 1991b) that designated Snake River sockeye salmon as an endangered species.

In September 1994, in response to a petition seeking protection for Baker Lake, WA sockeye salmon under the ESA and more general concerns about the status of West Coast salmon and steelhead, NMFS initiated a coastwide status review of sockeye salmon in Washington, Oregon, and California, and formed a Biological Review Team (BRT) to conduct the review. After considering available information on genetics, phylogeny and life history, freshwater ichthyo-geography, and environmental features that may affect sockeye salmon, the BRT identified six ESUs (Ozette Lake, Okanogan River, Lake Wenatchee, Quinault Lake, Baker River, and Lake Pleasant) and one provisional ESU (Big Bear Creek). The BRT reviewed population abundance data and other risk factors for these ESUs and concluded that one (Ozette Lake) was likely to become endangered in the foreseeable future, and that the remaining ESUs were not in significant danger of becoming extinct or endangered, although there were substantial conservation concerns for some of these (Gustafson et al. 1998). In March 1998, NMFS published a proposed rule to list the Ozette Lake ESU as threatened under the ESA, and to place the Baker River ESU on the candidate list. Due to the lack of natural spawning habitat and the vulnerability of the entire population to problems in artificial habitats, NMFS proposed to add the Baker River ESU to the list of candidate species (NMFS 1998). Subsequently, based on the updated NMFS status review (WCSSBRT 1999) and other information received, NMFS published its final listing determination (NMFS 1999) that designated the Ozette Lake sockeye salmon ESU as threatened and removed the Baker River ESU from the candidate list.

In considering the ESU status of resident forms of *O. nerka*, the key issue is evaluating the strength and duration of reproductive isolation between resident and anadromous forms. Many kokanee populations appear to have been strongly isolated from sympatric sockeye populations for long periods of time. Since the two forms experience very different selective regimes over their life cycle, reproductive isolation provides an opportunity for adaptive divergence in sympatry. Kokanee populations that fall in this category will generally not be considered part of sockeye ESUs. On the other hand, resident fish appear to be much more closely integrated into some sockeye populations. For example, in some situations, anadromous fish may give rise to progeny that mature in freshwater (as is the case with residual sockeye), and some resident fish may have anadromous offspring. In these cases, where there is presumably some regular, or at least episodic, genetic exchange between resident and anadromous forms, they should be considered part of the same ESU. The sockeye salmon BRT[1] met in January 2003 to discuss new data received and to determine if the new information warranted any modification of the conclusions of the original BRTs. This report summarizes new information and the preliminary BRT conclusions on the following ESUs: Snake River in Idaho and Ozette Lake in Washington.

[1] The Biological Review Team (BRT) for the updated status review for West Coast Sockeye Salmon included Thomas Cooney, Dr. Richard Gustafson, Dr. Robert Iwamoto, Gene Matthews, Dr. Paul McElhany, Dr. Mary Ruckelshaus, Dr. Thomas Wainwright, Dr. Robin Waples, Dr. John Williams, and Dr. Gary Winans, from NMFS Northwest Fisheries Science Center (NWFSC); Dr. Peter Adams and Dr. Eric Bjorkstedt, from NMFS Southwest Fisheries Science Center (SWFSC); and Dr. Reg Reisenbichler from the Northwest Biological Science Center, USGS Biological Resources Division, Seattle.

D.2.1 SNAKE RIVER SOCKEYE

D.2.1.1 Previous BRT Conclusions

The first formal ESA status review for salmon in the Pacific Northwest was conducted as a response to a 1990 petition to list sockeye salmon from Redfish Lake in Idaho as an endangered species. The distinctiveness of this population became apparent early in the process: it spawns at a higher elevation (2,000m), and has a longer freshwater migration (1,500 km) than any other sockeye salmon population in the world (Waples et al. 1991). Nor was the precarious nature of the anadromous run in doubt: in the fall of 1990, during the course of the status review, no adults were observed at Lower Granite Dam or entering the lake, and only one fish was observed in each of the two previous years. However, a population of kokanee also existed in Redfish Lake, and the relationship between the sockeye and kokanee was not well understood. This issue was complicated by uncertainty regarding the effects of Sunbeam Dam, which stood for over 2 decades about 20 miles downstream of Redfish Lake. By all accounts, the dam was a serious impediment to anadromous fish, but opinions differed as to whether it was an absolute barrier. Some argued that the original sockeye population in Redfish Lake was extirpated as a result of Sunbeam Dam, and that adult returns in recent decades were simply the result of sporadic seaward drift of kokanee (Chapman et al. 1990). According to this hypothesis, the original sockeye gene pool was extinct and the remaining kokanee population was not at risk because of its reasonably large size (ca. 5,000-10,000 spawners per year). An alternative hypothesis held that the original sockeye salmon population managed to persist in spite of Sunbeam Dam, either by intermittent passage of adults or recolonization from holding areas downstream of the dam. The fact that the kokanee population spawns in the inlet stream (Fishhook Creek) in August-September and all the recent observations of sockeye spawning have been on the lake shore in October-November was cited as evidence that the sockeye and kokanee represent separate populations. According to this hypothesis, the sockeye population was critically endangered, and perhaps, on the brink of extinction.

At the time of the status review, the BRT unanimously agreed that there was not enough information to determine which of the above hypotheses were true (Waples 1991). Although the kokanee population had been genetically characterized and determined to be quite distinctive compared to other *O. nerka* populations in the Pacific Northwest, no adult sockeye were available for sampling, so the BRT could not evaluate whether the two forms shared a common gene pool. When pressed to make a decision regarding the ESU status of Redfish Lake *O. nerka*, the BRT concluded that, because they could not determine with any certainty that the original sockeye gene pool was extinct, they should assume that it did persist and was separate from the kokanee gene pool. This conclusion was strongly influenced by consideration of the irreversible consequences of making an error in the other direction (*i.e.*, if the species was not listed based on the assumption that kokanee and sockeye populations were a single gene pool and this later proved not to be the case, the species could easily go extinct before the error was detected).

The status review of Redfish Lake sockeye salmon is the only instance in which the BRT has been asked to apply the precautionary principle in its deliberations. In subsequent evaluations, when the "best available scientific information" was insufficient to distinguish with any certainty among competing hypotheses regarding key ESA questions, the BRT has simply reported this result and tried to characterize the degree of uncertainty in the team's conclusions. Decisions about how best to apply the precautionary principle in the face of uncertainty in making listing determinations have been left to the NMFS management/policy arm.

Based on results of the status review, NMFS proposed a listing of Redfish Lake sockeye as endangered in April 1991. When finalized in late 1991, this represented the first ESA listing of a Pacific salmon population in the Pacific Northwest. At the time of the listing, the only population that the BRT and NMFS were confident belonged in this ESU was the beach spawning population of sockeye from Redfish Lake. Historical records indicated that sockeye once occurred in several other lakes in the Stanley Basin, but no adults had been observed in these lakes for many decades and their relationship to the Redfish Lake ESU was uncertain.

D.2.1.2 New Data and Analyses

Four adult sockeye returned to Redfish Lake in 1991; these were captured and taken into captivity to join several hundred smolts collected in spring 1991 as they outmigrated from Redfish Lake. The adults were spawned, and their progeny reared to adulthood along with the outmigrants as part of a captive broodstock program, whose major goal was to perpetuate the gene pool for a short period of time (one or two generations) to give managers a chance to identify and address the most pressing threats to the population. As a result of this program and related research, a great deal of new information has been gained about the biology of Redfish Lake *O. nerka* and limnology of the lakes in the Stanley Basin. Genetic data collected from the returning adults and the outmigrants showed that they were genetically similar but distinct from the Fishhook Creek kokanee. However, otolith microchemistry data (Rieman et al. 1994) indicated that many of the outmigrants had a resident female parent. These results inspired a search of the lake for another population of resident fish that was genetically similar to the sockeye. These efforts led to discovery of a relatively small number (perhaps a few hundred) kokanee-sized fish that spawn at approximately the same time and place as the sockeye. These fish, termed "residual" sockeye salmon, are considered to be part of the listed ESU.

Subsequent genetic analysis (Winans et al. 1996, Waples et al. 1997) has established the following relationships between extant populations of *O. nerka* from the Stanley Basin and other populations in the Pacific Northwest: 1) native populations of *O. nerka* from the Stanley Basin (including Redfish Lake sockeye and kokanee and Alturas Lake kokanee) are genetically quite divergent from all other North American *O. nerka* populations that have been examined; 2) within this group, Redfish Lake sockeye and kokanee are genetically distinct, and Alturas Lake kokanee are most similar to Redfish Lake kokanee; 3) two gene pools of *O. nerka* have been identified in Stanley Lake—one may be the remnant of a native gene pool that survived rotenone treatments in the lake, while the other can be traced to introductions from Wizard Falls Hatchery in Oregon; 4) no trace of the original gene pool of *O. nerka* has been found in Pettit Lake. The population that has spawned in Pettit Lake in recent decades can be traced to introductions of kokanee from northern Idaho, and those populations in turn can be traced to stock transfers of Lake Whatcom (Washington) kokanee early in the last century.

Between 1991 and 1998, 16 naturally-produced adult sockeye returned to the weir at Redfish Lake (Table D.2.1.1) and were incorporated into the captive broodstock program.

Table D.2.1.1. Adult anadromous sockeye salmon returns to the Redfish Lake Creek weir 1954-1968 (Bjornn et al. 1968) and the Redfish Lake Creek trap and Sawtooth Fish Hatchery weir (1991-2002) (L. Hebdon, IDFG, pers. comm.). No data are available for 1967-1984.

Year	Adults	Year	Adults
1954	998	1979	
1955	4,361	1980	
1956	1,381	1981	
1957	523	1982	
1958	55	1983	
1959	290	1984	
1960	75	1985	11
1961	11	1986	29
1962	39	1987	16
1963	395	1988	1
1964	335	1989	1
1965	17	1990	0
1966	61	1991	4
1967		1992	1
1968		1993	8
1969		1994	1
1970		1995	0
1971		1996	1
1972		1997	0
1973		1998	1
1974		1999	7[1]
1975		2000	257[1]
1976		2001	26[1]
1977		2002	22[1]
1978			

[1] Progeny of captive broodstock program

This program, overseen by the Stanley Basin Sockeye Technical Oversight Committee, has produced groundbreaking research in captive broodstock technology (Hebdon et al. 1999, Kline and Willard 2001, Frost et al. 2002) and limnology (Kohler et al. 2002). The program has utilized three different rearing sites to minimize chances of catastrophic failure and has produced several hundred thousand eggs and juveniles, as well as several hundred adults, for release into the wild (Table D.2.1.2). A milestone was reached in 2000, when > 200 adults from the program returned to Redfish Lake. Currently, the captive broodstock program is being maintained as a short-term safety net, pending decisions about longer-term approaches to recovery of the ESU.

The Snake River Salmon Recovery Team (Bevan et al. 1994; NMFS 1995) suggested that to be considered recovered under the ESA, this ESU should have viable populations in three different lakes, with at least 1,000 naturally produced spawners per year in Redfish Lake and at least 500 in each of two other Stanley Basin lakes. As a step toward addressing this recommendation, releases of progeny from the Redfish Lake captive broodstock program have been made in Pettit Lake and Alturas Lake as well. In 1991, about 100 outmigrants from Alturas

Table D.2.1.2. Summary of releases of progeny from the Redfish Lake captive broodstock program into Redfish, Alturas, and Pettit Lakes (L. Hebdon, IDFG, pers. comm.).

Redfish Lake releases		(Thousands, except adults)		
	Eggs	Presmolts	Smolts	Adults
1993				20
1994		14		65
1995		82	4	
1996	105	2	12	120
1997	85	152		80
1998		95	38	
1999		24	5	21
2000		48		120
2001		43	14	69
2002		107	39	190
Alturas Lake releases				
	Eggs	Presmolts	Smolts	Adults
1995				
1996				
1997	20	100		20
1998		39		
1999		13		
2000		12		77
2001		12		
2002		6		
Pettit Lake releases				
	Eggs	Presmolts	Smolts	
1995		9		
1996				
1997		9		
1998		7		
1999	20	3		
2000	65	6		
2001		11		
2002	31	28		

Lake were collected at the same time as the Redfish Lake outmigrants and reared to maturity as a separate population in captivity. However, because of funding and space limitations and uncertainties about priorities for propagating this population, the resulting adults were released into the lake rather than being kept for spawning and another generation of captive rearing. Because the Alturas Lake kokanee spawn earlier than Redfish lake sockeye and in the inlet stream, it is hoped that the introduction of Redfish Lake sockeye into Alturas Lake will not adversely affect this native gene pool.

D.2.2 OZETTE LAKE SOCKEYE

D.2.2.1 Summary of Previous BRT Conclusions

Status and trends

The 5-year average (geometric mean) estimated abundance of Ozette Lake sockeye for the period 1994-1998 was 580, slightly below the average of 700 (for the years 1992-1996) reported by Gustafson et al. (1997). This decrease is largely because the earlier average included two dominant brood-cycle years, while the recent average includes only one. The 1998 count of 984 was substantially above the count of 498 that was observed 4 years (one generation) earlier. This may result primarily from a change in counting methods; a video camera was installed in 1998 and the operation period of the weir was expanded (7 May-14 August), resulting in a more complete count of all fish passing the weir (M. Crewson, Makah Indian Tribe, pers. comm., 21 August 1998). It is likely that counts for previous years underestimated total spawner abundance, but the magnitude of this bias is unknown.

Analyses of trends using data through 1998 indicates that the short-term (10-year) trend improved from a decline of 9.9% per year in Gustafson et al. (1997) to a relatively low 2% annual increase. How much this was influenced by the change in counting methods in 1998 is not known. The long-term trend remained slightly downward (-2%).

Threats

A variety of threats to the continued existence of the sockeye populations in Ozette Lake were identified, including siltation of beach spawning habitat, and potential genetic effects of past interbreeding with genetically dissimilar kokanee. The BRT received an analysis of logging history in the Ozette Basin from Rayonier Northwest Forest Resources (Meier 1998). This analysis indicated that most logging in the basin occured since the mid-1950s: in 1953, only 8.7% of the basin had been logged, while 60% had been logged by 1981. Thus, logging occurred largely after the substantial decline in sockeye salmon catch in the early 1950s.

BRT conclusions

The BRT last reviewed the Ozette Lake sockeye ESU status in November 1998. Their conclusion was that the ESU was likely to become endangered in the foreseeable future. Main uncertainties arose from questions about the reliability of abundance estimates and the historical presence of inlet-spawning sockeye salmon in the basin. Perceived risks were focused on low current abundance and trends and variability in abundance. At the time of the last status assessment, escapements averaging below 1,000 adults per year implied a moderate degree of risk from small-population genetic and demographic variability, with little room for further declines before abundances reach critically low levels. Other concerns included siltation of beach spawning habitat, very low abundance now compared to harvests in the 1950s, and potential genetic effects of past interbreeding with genetically dissimilar kokanee.

Listing status—Threatened

D.2.2.2 Summary of New Information

ESU status at a glance

Historical peak abundance	3,000-18,000
Historical populations	1+
Extant populations	1
5-year geometric mean escapement	2,267

ESU structure

The Puget Sound TRT considers the Ozette Lake sockeye ESU to be comprised of one historical population, with substantial substructuring of individuals into multiple spawning aggregations. The primary existing spawning aggregations occur in two beach locations—Allen's and Olsen's beaches, and in two tributaries, Umbrella Creek and Big River (both of the tributary spawning groups were initiated through a hatchery introduction program). Recently, mature adults have been located at other beach locations within the lake (e.g., Umbrella beach, Ericson's Bay, Baby Island, and Boot Bay), but whether spawning occurred in those locations is not known (Makah Fisheries 2000). Similarly, occasional spawners are found sporadically in other tributaries to the lake, but not in as high numbers or as consistently as in Umbrella Creek. The Umbrella Creek spawning aggregation was started through collections of lake-spawning adults as initial broodstock, and in recent years, all broodstock has been collected from returning adults to Umbrella Creek (Makah Fisheries 2000). The extent to which sockeye spawned historically in tributaries to the lake is controversial (Gustafson et al. 1997), but it is clear that multiple beach-spawning aggregations of sockeye occurred historically, and that genetically distinct kokanee currently spawn in large numbers in all surveyed lake tributaries (except Umbrella Creek and Big River). The two remaining beach-spawning aggregations are probably fewer than the number of aggregations that occurred historically, but there is insufficient evidence to determine how many subpopulations occurred in the ESU historically.

Much of the existing spawning in recent years occurs in the spawning aggregation created via fry releases into Umbrella Creek. The status of the historically well-documented spawning aggregations at Allen's and Olsen's beaches is not well understood because of the difficulties in observing spawners and sampling carcasses in the tannin-rich lake.

Updated status information

Because of the concerns about the status of Ozette Lake sockeye, the Lake Ozette Steering Committee was established (comprised of the Makah tribe, Olympic National Park, WDFW, and citizen groups) to organize recovery activities for sockeye. Makah Fisheries initiated a hatchery program designed to supplement existing beach spawners in 1983 (beach spawner supplementation ceased with the 1995 broodyear) and later to introduce sockeye to lake tributaries (intentional releases to tributaries began in broodyear 1992) (see *Updated Threats Information*). Therefore, all of the abundance information presented contains an unknown fraction of hatchery fish.

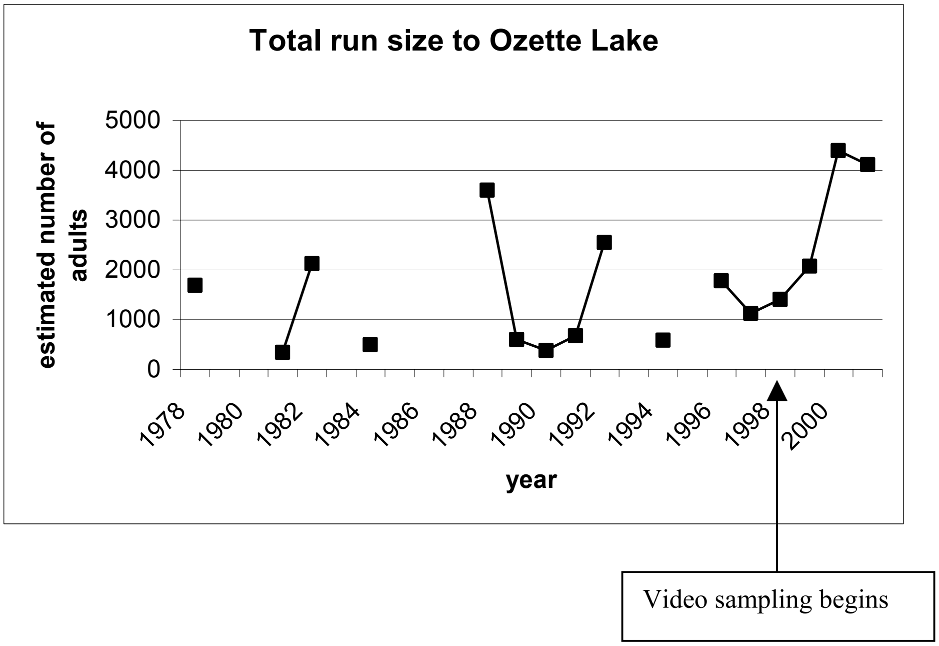

Figure D.2.2.1. Estimated numbers of adult sockeye entering Lake Ozette from 1978 to 2001. (Source: Mike Crewson, Makah Fisheries, unpublished data).

Information on abundance of Ozette Lake sockeye comes from visual counts at a weir across the lake outlet, therefore the counts presented represent total run size. The estimates of total run size have been revised upwards since the time of the last status review in 1997, due to resampling of data using new video camera counting technology (Figure D.2.2.1). The Makah Fisheries biologists estimate that previous counts of adult sockeye returning to the lake have been underestimates, and they have attempted to correct run-size estimates based on their assessments of human error and variations in inter-annual run-timing (Makah Fisheries 2000; Table D.2.2.1). The run-size estimates are very uncertain—an estimate of the 95% confidence interval around the 2001 count is N = 3,717 (2,815 – 5,416) (J. Fieberg memo to A. Ritchie and M. Crewson, September, 2002). The most recent 5-year geometric mean of sockeye returning to Ozette Lake is 2,267 adults. Since run-size estimates before 1998 are likely to be even more unreliable than recent counts, and the new counting technology has resulted in an increase in estimated run sizes, no statistical estimation of trends is reported. The current trends in abundance are unknown for the beach spawning aggregations. Although overall abundance appears to have declined from historical levels, it is not known whether this resulted in fewer spawning aggregations, lower abundances at each aggregation, or both.

The adults remain in the lake for an extended period of time (return April-August; spawn late October-February) before spawning on beaches or in the tributaries, and the pre-spawning mortality is not known. Therefore, it is not clear what the escapement levels to the spawning aggregations might be.

Table D.2.2.1. Estimated run size, natural origin recruits (NOR) to Lake Ozette and to Umbrella Creek (UC), and the fraction of fish returning to Umbrella Creek that are of hatchery origin in Lake Ozette sockeye salmon from 1978-2001 (Makah Fisheries 2000, M. Crewson, Makah Fisheries, unpublished data).

Year	Total Run Size	Lake NOR	UC NOR	UC Hatchery Origin
1978	1,690	nd	nd	nd
1979	nd	nd	nd	nd
1980	nd	nd	nd	nd
1981	350	nd	nd	nd
1982	2,123	nd	nd	nd
1983	nd	nd	nd	nd
1984	502	nd	nd	nd
1985	nd	nd	nd	nd
1986	nd	nd	nd	nd
1987	nd	nd	nd	nd
1988	3,599	nd	nd	nd
1989	603	nd	nd	nd
1990	385	nd	nd	nd
1991	684	nd	nd	nd
1992	2,548	nd	nd	nd
1993	nd	nd	nd	nd
1994	585	nd	nd	nd
1995	nd	nd	nd	44
1996	1,778	1,699	79	0
1997	1,133	998	nd	135
1998	1,406	1,310	nd	96
1999	2,076	1,676	149	251
2000	4,399	1,293		3,106
2001	4,116	591	3,525	

The sockeye returning to Umbrella Creek have averaged more than 10% of the total run size to Lake Ozette from 1995 to 1999, and possibly this fraction has been higher in the last 2 years (Makah Fisheries 2000, Mike Crewson, Makah Fisheries, pers. comm.). A portion of the Umbrella creek hatchery sockeye were marked as juveniles beginning in the late 1980s, and results of monitoring of these marks on returning adults indicates that natural origin spawners in Umbrella Creek in 1999 ranged from 21.4%-52.9% (Makah Fisheries 2000).

Age data from otolith samples in 2000 and 2001 in Umbrella Creek, Allen's and Olsen's beaches suggest that a small fraction of 5-year old fish do occur in Umbrella Creek and Olsen's beach subpopulations (Table D.2.2.2). Previous estimates of returns from different brood years will be affected by these age data, since early analyses assumed 100% 4-year old sockeye.

Based on examination of carcasses retrieved from Allen's and Olsen's beaches for otolith marks applied to hatchery fish, straying of hatchery fish from the Umbrella Creek program appears to be very low (Makah Fisheries 2000).

Table D.2.2.2. Percentages of 5-year old fish sampled from otoliths in carcasses in sockeye subpopulations in Lake Ozette (Source: M. Crewson, Makah Fisheries, pers. commun.).

	% 5-year olds	
Sub-population	**2000 (n samples)**	**2001 (n samples)**
Olsen's beach	2.1% (47)	1.2% (81)
Allen's beach	0% (51)	0% (7)
Umbrella creek	3.8% (183)	18.5% (195)*

*One out of 195 fish sampled from Umbrella Creek was a 6-year old

Updated threats information

The Makah Fisheries staff has been working with the Lake Ozette steering committee to identify factors for decline in Ozette Lake sockeye. Thus far, primary sources of threats to VSP parameters include: 1) loss of adequate quality and quantity of spawning and rearing habitat, 2) predation and disruption of natural predator-prey relationships, 3) introduction of non-native fish and plant species, 4) past over-exploitation, 5) poor ocean conditions, and 6) interactions among those factors. There has been no directed harvest on Ozette Lake sockeye since 1982, and commercial fisheries stopped in 1974 (Gustafson et al. 1997, Makah Fisheries 2000).

Previous releases of hatchery fish in Ozette Lake have been relatively low magnitude, but some of the releases were from sockeye stocks outside the ESU or were from Ozette kokanee-sockeye hybrids (Gustafson et al. 1997). The latest artificial propagation program in Ozette Lake has focused on sockeye introductions into Big River and Umbrella Creek tributaries; chosen because of their apparent suitable spawning habitat and relatively low numbers of naturally spawning kokanee. The Umbrella Creek hatchery has been in place since 1982. The first egg source was from the Quinault River, and progeny were hatched at Umbrella Creek, reared in a net pen in Ozette Lake, and released in June of 1983. From 1983 to 1999, all eggs were collected from Olsen's or Allen's beach spawners. Beginning in 2000, the source for future broodstock for tributary releases will be from returns to tributaries, primarily Umbrella Creek. The SSHAG group (2003) determined that the Umbrella Creek hatchery stock would have a category score of 1 or 2 (see Appendix D.1).

Predation on Ozette Lake sockeye by harbor seals and river otters has been monitored by the Makah Tribe and the NMFS Marine Mammal Lab, and biologists believe that pre-spawning predation rates could be significant. Predation by both otters and seals has been observed in the lake and in the outlet river, especially in the vicinity of the counting weir (Makah Fisheries 2000). In addition, predation scars (ranging from scratches to bite marks to lack of heads) on carcasses sampled and adults counted are noted.

The majority of Ozette Lake and the Ozette River lie within the boundaries of Olympic National Park; but the majority of the land in the Ozette Lake watershed is owned by private timber companies (Makah Fisheries 2000). Recent accelerated timber harvest, road-building activity, and forest practice and water quality violations are reported in a recent analysis by the Makah Tribe (Makah Fisheries 2000). New activities related to mitigating and improving degraded habitat quality could include the Forest and Fish Agreement (if implemented).

D.3. PRELIMINARY SOCKEYE BRT CONCLUSIONS

Ozette Lake

A majority of the BRT votes for this ESU were cast in the "likely to become endangered" category, with the remainder about equally split between the "danger of extinction," and "not likely to become endangered" categories. Moderately high concerns for all VSP elements are indicated by mean risk matrix scores ranging from 3.0 for diversity to 3.8 for spatial structure (Table D.3.1). Risk assessment for this ESU continues to be hampered by very incomplete data. Although significant efforts to improve this situation have been taken recently, the process of perfecting the new techniques and adjusting for biases in previous data is still in progress. It appears that overall abundance is low for a population that represents an entire ESU and may be substantially below historic levels. The BRT was concerned about reports that habitat degradation in the lake has resulted in loss of numerous sites suitable for beach spawners, but accurately assessing the situation is difficult because of poor visibility in the lake. The number of returning adults in the last few years has increased, but a substantial (but uncertain) fraction of these appear to be of hatchery origin, leading again to uncertainty regarding growth rate and productivity of the natural component of the ESU. Another uncertainty noted by the BRT related to reports that pre-spawning predation by harbor seals and river otters may be significant, but how large a factor this is and how it compares with historic patterns is not known.

Redfish Lake

The BRT was unanimous in assessing the status of this ESU: 100% of the likelihood votes were in the "danger of extinction" category. Mean risk matrix scores were extremely high (4.9-5.0) for every VSP element (Table D.3.1). On the positive side, the captive broodstock program initiated as an emergency measure in 1991 has at least temporarily rescued this ESU from the brink of extinction, and associated research has provided a great deal of information about the biology of this species and its environment. Return of over 200 adults from the hatchery program in 2000 is considered encouraging, but the status of the natural population remains extremely precarious. Only 16 naturally produced adults have returned since the listing in 1991, and all have been taken into the captive program.

Table D.3.1. Summary of risk scores (1 = low to 5 = high) for four VSP categories (see section "Factors Considered in Status Assessments" for a description of the risk categories) for the two sockeye ESUs reviewed. Data presented are means (range).

ESU	Abundance	Growth Rate/Productivity	Spatial Structure and Connectivity	Diversity
Redfish Lake	5.0 (5-5)	5.0 (5-5)	4.9 (4-5)	5.0 (5-5)
Lake Ozette	3.7 (3-4)	3.5 (3-4)	3.8 (3-5)	3.0 (2-4)

D.4 REFERENCES

Atkinson, C. E., J. H. Rose, and O. T. Duncan. 1967. Salmon of the North Pacific Ocean--Part IV. Spawning populations of North Pacific salmon. 4. Pacific salmon in the United States. Int. North Pac. Fish. Comm. Bull. 23:43-223.

Bevan, D., J. Harville, P. Bergman, T. Bjornn, J. Crutchfield, P. Klingeman, and J. Litchfield. 1994. Snake Salmon Recovery Team: final recommendations to the National Marine Fisheries Service. May 1994. Rob Jones, Recovery Plan Coordinator. National Marine Fisheries Service, Portland, Oregon.

Bjornn, T. C., D. R. Craddock, and D. R. Corley. 1968. Migration and survival of Redfish Lake, Idaho, sockeye salmon, *Oncorhynchus nerka*. Trans. Am. Fish. Soc. 97(4): 360-373.

Burgner, R. L. 1991. Life history of sockeye salmon *Oncorhynchus nerka*. *In* C. Groot and L. Margolis (editors), Pacific salmon life histories, p. 3-117. Univ. British Columbia Press, Vancouver, B.C., Canada

Chapman, D. W., W. S. Platts, D. Park, and M. Hill. 1990. Status of Snake River sockeye salmon. Final report, 90 p. (Available from Pacific Northwest Utilities Conference Committee, 101 SW Main Street, Suite 810, Portland, OR 97204.)

Frost, D. A., W. C. McAuley, D. J. Maynard, and T. A. Flagg. 2002. Redfish Lake sockeye salmon captive broodstock rearing and research, 2001, Annual Report. Report to Bonneville Power Administration, Contract No. 00004464, Project No. 199204000, 27 electronic pages (BPA Report DOE/BP-00004464-1). (Available online at: http://www.efw.bpa.gov/Environment/EW/EWP/DOCS/REPORTS/HATCHERY/A00004464-1.pdf)

Gustafson, R. G., T. C. Wainwright, G. A. Winans, F. W. Waknitz, L. T. Parker, and R. S. Waples. 1997. Status review of sockeye salmon from Washington and Oregon. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-33, 282 p.

Hebdon, J. L., M. Elmer, and P. Kline 1999. Snake River sockeye salmon captive broodstock program research element. Annual Progress Report January 1, 1999–December 31, 1999. Report to Bonneville Power Administration, Contract No. 00000167-00001, Project No. 199107200, 56 electronic pages (BPA Report DOE/BP-00000167-1). (Available online at: http://www.efw.bpa.gov/ Environment/EW/EWP/DOCS/REPORTS/HATCHERY/A00000167-1.pdf)

Kline, P. A., and C. Willard. 2001. Snake River sockeye salmon captive broodstock program hatchery element. Annual Progress Report January 1, 2000 - December 31, 2000. Report to Bonneville Power Administration, Contract No. 00000167, Project No. 199107200, 42 electronic pages. (BPA Report DOE/BP-00000167-2) (Available online at: http://www.efw.bpa.gov/Environment/EW/EWP/DOCS/REPORTS/HATCHERY/A00000167-2.pdf)

Kohler, A., R. Griswold, and D. Taki, Snake River sockeye salmon habitat and limnological research. Project No. 9107-100, 97 electronic pages, (BPA Report DOE/BP-00004343-3). (Available online at: http://www.efw.bpa.gov/ Environment/EW/EWP/DOCS/REPORTS/HABITAT/H00004343-3.pdf)

Makah Fisheries Management. 2000. Lake Ozette sockeye hatchery and genetic management plan. Biological Assessment Section 7 consultation. Prepared by Makah Fisheries Management for Bureau of Indian Affairs. October 23, 2000.

Meier, R. 1998. Letter from R. Meier (Rayonier Northwest Forest Resources) to G. Griffin (Protected Resources Division, NMFS Northwest Region) dated 22 June 1998, re. "Comments on 'Endangered and threatened species: proposed threatened status and designated critical habitat for Ozette Lake, Washington sockeye salmon.'" 9 pp. + attachments.

NMFS (National Marine Fisheries Service). 1990. STATUS REVIEW: Listing Endangered and Threatened Species; Notice of Status Review for Sockeye Salmon (*Oncorhynchus nerka*). Federal Register [April 9, 1990] 55(68): 13181-13182.

NMFS (National Marine Fisheries Service). 1991a. PROPOSED RULE: Endangered and Threatened Species; Proposed Endangered Status for Snake River Sockeye Salmon. Federal Register [Docket 910379-107, April 5, 1991] 56(66): 14055-14067.

NMFS (National Marine Fisheries Service). 1991b. FINAL RULE: Endangered and Threatened Species; Endangered Status for Snake River Sockeye Salmon. Federal Register [Docket 910379-1256, November 20, 1991] 56(224): 58619-58624.

NMFS (National Marine Fisheries Service). 1995. Federal Register Vol. 60, No. 74, [I.D. 040795A] Endangered and Threatened Wildlife and Plants; Notice of Availability of a Proposed Recovery Plan for Review and Comment; Public Hearings. April 18, 1995. p. 19388.

NMFS (National Marine Fisheries Service). 1998. PROPOSED RULE: Endangered and threatened species: Proposed threatened status and designated critical habitat for Ozette Lake, Washington sockeye salmon. Federal Register [Docket 980219043-8043-01, March 10, 1998] 63(46): 11750-11771.

NMFS (National Marine Fisheries Service). 1999. FINAL RULE: Endangered and Threatened Species; Threatened Status for Ozette Lake Sockeye Salmon in Washington. Federal Register [Docket 980219043–9068–02, March 25, 1999] 64(57): 14528-14536.

Ricker, W. E. 1938. "Residual" and kokanee salmon in Cultus Lake. J. Fish. Res. Board Can. 4(3):192-218.

Rieman, B. E., D. L. Myers, and R. L. Nielsen. 1994. Use of otolith microchemistry to discriminate *Oncorhynchus nerka* of resident and anadromous origin. Can. J. Fish. Aquat. Sci. 51:68-77.

SSHAG (Salmon Steelhead Hatchery Assessment Group). 2003. Hatchery Broodstock Summaries and Assessments for Chum Salmon, Coho Salmon, Chinook Salmon, and Steelhead within Listed and ESUs. Technical review draft. NMFS Northwest and Southwest Fisheries Science Centers.

Waples, R. S. 1991a. Pacific salmon, Oncorhynchus spp., and the definition of "species" under the Endangered Species Act. Mar. Fish. Rev. 53(3):11-22.

Waples, R. S., O. W. Johnson, and R. P. Jones, Jr. 1991. Status review for Snake River sockeye salmon. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-195, 23 p.

Waples, R. S., O. W. Johnson, and R. P. Jones, Jr. 1991. Status review for Snake River sockeye salmon. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-195, 23 p.

Waples, R. S., P. B. Aebersold, and G. A. Winans. 1997. Population genetic structure and life history variability in *Oncorhynchus nerka* from the Snake River Basin. Final Report of Research, Bonneville Power Administration, Portland, OR, 104 p.

WCSSBRT (West Coast Sockeye Salmon Biological Review Team). 1999. Status review update for sockeye salmon from Ozette Lake and Baker River, Washington. Internal memo. 40 p. (Available at: http://www.nwr.noaa.gov/1salmon/salmesa/pubs/ sru981217.pdf).

Winans, G. A., P. B. Aebersold, and R. S. Waples. 1996. Allozyme variability of *Oncorhynchus nerka* in the Pacific Northwest, with special consideration to populations of Redfish Lake, Idaho. Trans. Am. Fish. Soc. 125:645-663.

Wood, C. C. 1995. Life history variation and population structure in sockeye salmon. *In* J. L. Nielsen (editor), Evolution and the aquatic ecosystem: defining unique units in population conservation. Am. Fish. Soc. Symp. 17:195-216.

D.5. APPENDICES

Appendix D.5.1. Preliminary SSHAG (2003) categorizations of hatchery populations of the Ozette Lake sockeye ESU. See "Artificial Propagation" in General Introduction for explanation of the categories.

ESU	Stock	Run	Basin	SSHAG Category
Ozette Lake	Umbrella Creek		Ozette	1 or 2