Red List Category & Criteria:	Critically Endangered A4abcd ver 3.1
Year Assessed:	2006
Assessor/s	Rand, P.S.
Reviewer/s:	Augerot, X, Whorisky, F. & Members of the Salmonid Specialist Group (Salmonid Red List Authority)
Contributor/s:	

Justification:
Listed as Critically Endangered but plausible categories include Critically Endangered, Endangered. Determined using RAMAS Red List software. We used the software default settings for dispute tolerance and risk tolerance.

The IUCN criteria used to estimate the population size reduction for a species can include the following: direct observations, indices of abundance, declines in area of occupancy or extent of occurrence and/or quality of the habitat, actual or potential levels of exploitation, or effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites. We relied on four primary sources of information to document declines in population abundance (in Russia) and habitat (in Japan). Below we include documentation of our data sources and our analytical approaches:

1. Khabarovsk bycatch time series

We obtained data on bycatch of Sakhalin taimen in commercial fisheries (primarily gill net captures) along the Sea of Japan coast in Khabarovsk during 1951–1998. These data have been reported in a number of publications (Zolotukhin *et al*. 2000, Zolotukhin *et al*. 2002). Data are reported as weight (in 1,000 kg) of landed biomass of taimen (see Figure 2 in the attached PDF). We parsed the data into three discrete periods to account for different prevailing social and economic conditions for the fishery. We identified the first period (1951–1964) as the most reliable time series, where bycatch reporting rate was high and consistent. We fit a exponential model to these data and estimated a rate of decline of the regional population at -9% yr^{-1}. Assuming an average weight of captured taimen at 5 kg, the total harvest during this period ranged from ~800 to ~4,000 individuals yr^{-1}, most likely representing the peak bycatch fishery yield for the species in this region. We fit an exponential model to a second time series that extended from 1972–1979, a period marked by a growing black market for the species, resulting in under-reported bycatch. The rate of decline during this period was estimated at -23% yr^{-1}. We fit the remaining data in the time series (1980–1998) to a separate exponential model. This period can be characterized by continued under-reporting of bycatch, and includes recreational landings beginning in the mid-1990s. The model fit to these data suggested the regional population declined by -12% yr^{-1}.

2. Sakhalin bycatch time series

We obtained data on bycatch of Sakhalin taimen in the commercial fishery located in the Nogliki region of Sakhalin Island during 1971–1997. These data were compiled by SakhNIRO, the regional fisheries agency on Sakhalin. Data are reported as weight (in 100 kg) of landed biomass of taimen (see Figure 3 in the attached PDF). Assuming an average weight for captured taimen at 5 kg, peak harvest during this time series was ~ 3,000 individuals yr^{-1}, occurring in 1974. We fit these data to an exponential model, and estimated the slope of the regression of log(catch) vs. year. This time series suggests a rate of reduction of the population of 11% yr^{-1} over the period of record (26 yr). The rate of decline of the older members of the population in the region is thought to be even more dramatic (S.N. Safronov, Sakhalin State University, pers. comm.).

3. Estimate of exploitation rate on the Koppi River population

Catch and age composition data from the Koppi River population was obtained during 2000-2002. Gill nets and angling were the primary methods of capture. Captured individuals were aged by scale analysis (N = 131). We fit a regression of log (catch) vs. age for individuals aged 3-16 to estimate Z, total instantaneous mortality rate of the population (see Figure 4 in the attached PDF). This assumes that taimen are fully recruited to the fishing gear by age 3, and that the age composition of the catch is representative of the true population in the river. Our estimate for Z is 0.307 (or -26 % yr^{-1}). Assuming natural mortality (M) to be 0.11 (see above), we estimated fishing mortality by difference (F = Z - M, F = 0.197). The resulting value for fishing mortality is ~ two times the rate of natural mortality of the population. Annual rate of fishing mortality is estimated at -18% yr^{-1}. This mortality rate is within the range of estimated population loss rates based on the bycatch time series for Khabarovsk estimated above (-9, -12, and -23% yr^{-1}). While this may be an overestimate of fishing mortality based on difficulties associated with sampling older, mature individuals in the Koppi River population, it does represent the most comprehensive effort to date to provide a reliable sample of the age composition and relative abundance of a river population of Sakhalin taimen.

4. Hokkaido taimen fry survey

Trend data for the species abundance in Hokkaido, Japan are not available. A comparison of results from redd surveys conducted during 1991 and 1998 in the Sarufutsu River in northern Hokkaido indicated no marked changes over time in spawner abundance for this population (M. Fukushima, JMOE unpubl. data). We feel that that this data set is not representative given the short period of observation, and that the region has seen much less change in land use compared to other regions in Hokkaido. Here we rely on a study on presence/absence for the species in Hokkaido to scale the magnitude of habitat loss for the species. Edo (2001) concluded that the range of the species has been reduced by 57% based on an extensive survey of juvenile taimen (fry, or young-of-the-year) during 2000. The survey involved electrofishing reaches in a total of 30 study streams that were thought to support the species historically (Edo 2001). Fry were observed in a total of 13 study streams, representing 43% of the historic range currently occupied. We acknowledge the likelihood of error by relying on fry absence based on a one-time survey as evidence of extirpation, but we feel this is the best available data to allow us to gauge habitat loss in this region. While numerous anecdotes exists for declining adult abundance in some river systems, we lack reliable time series data. One river, the Shiribetsu (located in southwestern Hokkaido), was recognized historically for it prized receational taimen fishery, but no longer supports adult spawners. Surveys for redds conducted since 1995 have indicated that this population has been extirpated (H. Kawamura, Hokkaido Fish Hatchery, pers. comm.).

Based on results of these analyses, and assuming a generation time of 14 yrs, we estimated regional population reductions over three generations (42 yr period) of 98% in Khabarovsk (based on -9% yr^{-1} using the most reliable time series), 99% in Sakhalin, and 57% in Hokkaido (based on range reduction using results of fry survey).

- **Geographic Range [top] Range Description:**

Russia and Japan (see Figure 1 in the attached PDF). Current distribution of Sakhalin taimen extends from approximately 43°N to 53°N latitude and 135°W and 145°W longitude. The Sakhalin taimen is restricted to the Russian Far East region including Primorye, Khabarovsk, and Sakhalin and Kuril Islands, and in Hokkaido, Japan.

We conducted a thorough investigation of the natural range of the species through contacts with experts familiar with Sakhalin taimen distribution. We would particularly like to identify the following individuals for providing input into this process: Dr. Sergei Zolotukhin (TINRO), Dr. Anatoly Semenchenko (TINRO), Mr. Sergei Makeev (Sakhalin Wild Nature Fund), Dr. S. N. Safranov (Sakhalin State University), and Dr. Michio Fukushima (JMOE).

We relied on the stream network developed in ArcGIS based on the Digital Chart of the World, based on a resolution of 1:1,000,000 (ESRI 1992). We generated a convex polygon that contained all the rivers known to support the species currently. The estimate of area delineated by this polygon is 332,153 km², excluding marine waters greater than 1 km offshore. We estimated the area of occupancy based on the sum of the individual basin areas that support the species, and marine waters extending 1 km offshore. Our estimate for the area of occupancy is 233,498 km². We assumed in both cases that the area is continuing to decline, but the species does not exhibit extreme fluctuations.

e: Countries
ı (Hokkaido); Russian Federation (Khabarovsk, Kuril Is., Primorye, Sakhalin)

e:
c – northwest **FAO Marine Fishing Areas**

- **Population [top] Population:**

Very little data exists on absolute population sizes for this species. Redd surveys have been conducted in a number of river systems in Hokkaido. This method is prone to error (see Dunham *et al*. 2001); however, it is the most commonly used method for enumerating adult abundance in this region. Estimates of total abundance generated from a redd survey by Edo (2001) for a number of Hokkaido rivers are as follows: Sorachi, 211; Uryu, 264; Bekanbeushi, 306; Toikanbetsu, 422; Kushiro, 21; Tokachi, 21; Shiribetsu, 0. We used data in Fukushima (1994) to estimate total spawner abundance of 153 individuals within two tributaries (Nino and Jyugo Creeks) of the Sarufutsu River in northwestern Hokkaido (assuming 2 redds per female and a 50:50 sex ratio) based on sampling conducted during 1992. To generate a Hokkaido-wide population estimate, we divided these population estimates by the total river km for each sampled river segment based on our ArcGIS stream coverage. This generated an average of 2.7 adult taimen km^{-1} (see Table 1 in the attached PDF). This density was used to estimate spawning abundance in river basins where we lack data. We excluded those rivers whose populations have been extirpated (Kubo 1990; Harako 1991). We estimated abundance of the regional population by adding the abundance of taimen in those basins where we have quantitative data to the estimated values of abundance predicted across the rest of the range by multiplying total river km in each basin by the density estimate of 2.7 taimen km^{-1}. This resulted in a value of 5,068 adults for the Hokkaido population (see Table 1 in the attached PDF).

We relied on best expert judgment, and consideration of the magnitude of bycatch of taimen in the commercial salmon fishery, to gauge levels of abundance for taimen in the Russian portion of the species range. Ranges of abundance were provided for 10 rivers along the Sea of Japan coast (1-100,101-1000,1001-10000 adults per basin), and 61 rivers on Sakhalin (1-50, 51-100, 101-1000 adults per basin). Because ranges were provided in this case, we estimated densities by basin (2.9-29.6 taimen km^{-1}, see Table 1 in the attached PDF) using the low and high value in each abundance strata. We assumed the density range estimated for Sakhalin applied to the Kuril Islands portion of the species range. Populations in five basins on Sakhalin Island are presently considered extirpated. To arrive at a total population for each region, we summed the population estimates (both low and high values in each strata) for the rivers where we had estimates, and extrapolated abundances based on total stream km in basins where we lack data. Our estimates for total population by region are as follows: Primorye: 2,796-28,323 adults, Khabarovsk: 3,351-33,520 adults, and Sakhalin (including Kuril Islands): 1,591-12,024 (see Table 1). The historic peaks of bycatch landings in the time series (Khabarovsk at ~ 4,000 adults yr^{-1} and Sakhalin at ~3,000 adults yr^{-1}, estimated by converting landed biomass to adult numbers assuming average weight of landed adult at ~ 5kg) fall within the range of abundances estimated here.

Population Trend: Decreasing

- **Habitat and Ecology [top] Habitat and Ecology:**

Preferred habitat for juvenile Sakhalin taimen is low gradient, coastal rivers (Fukushima 2000), and habitat for maturing and mature adults can extend into first and second order tributaries for spawning and lake and estuarine waters for feeding (Kawamura *et al*. 1983, Zolotukhin *et al*. 2000, Arai *et al*. 2004). Females construct redds (i.e. nests) at the lower ends of pools, where eggs are deposited into discrete egg pockets in benthic gravel (Fukushima 1994, Edo *et al*. 2000). Data suggests that the density of Sakhalin taimen redds is positively correlated with channel sinuosity (Fukushima 2000). Some populations on Hokkaido are thought to be restricted to freshwater, possibly related to their position near the southern limit of their range, as has been observed for *Salvelinus* spp. (e.g., Maekawa and Nakano 2002, Morita *et al*. 2005). The species is known to exhibit both freshwater and anadromous life histories. The species is long lived, slow growing and exhibits delayed age at maturity relative to other salmonids. The species is iteroparous (i.e. repeat spawns), and reaches sexual maturity at ages 6–8, and achieves peak fecundity at approximately age 15 (Zolotukhin *et al*. 2000). The species spawns during the spring to early summer, depending on location within their natural range. Peak spawning occurs during May-June along the Sea of Japan coast (Zolotukhin *et al*. 2000), late June in Sakhalin (Gritsenko *et al*. 1974), and mid-March to late April in eastern to northern Hokkaido (Kimura 1966, Fukushima 1994). Anadromous life history forms are thought to reside in estuarine waters during the summer growing season, and overwinter in lower reaches of rivers beginning in mid-September to late October (Zolotukhin *et al*. 2000). Diet is dominated by benthic invertebrates during years 1–2, followed by a transition to finfish and crustaceans as they mature. We fit a von

Bertalanffy growth model to size at age data for taimen sampled in the following rivers: Kievka and Samarga in Primorye, Russia, Koppi in Khabarovsk, Russia, and several rivers in eastern Hokkaido, Japan. Data for Kievka and Samarga are obtained from Zolotukhin *et al*. (2000), data from eastern Hokkaido populations are from Yamashiro (1965), and data for the Koppi was obtained from field collections during 2000-2002 (N = 131 individuals, ranging in age from 1 to 16 yr, S. Zolotukhin, TINRO, unpubl. data). We fit the equation with Microsoft Excel Solver and estimated best fit parameters for the model (see Figure 2 in the attached PDF). The parameters fit to the Koppi data set, representing our most comprehensive data set on size at age, are as follows: Linf (asymptotic length) = 227 cm TL (TL = total length), K (growth coefficient) = 0.07. Data in Figure 2 are plotted as FL (fork length, also known as AC in Russia), and values were converted to TL for model fitting using a length conversion equation of TL = 1.032*FL, Froese and Pauly 2005). Parameters for the other Russian populations were similar to the results for the Koppi. Growth for taimen in eastern Hokkaido appeared markedly lower than the Russian populations, and may be related to colder water temperatures characteristic of this region (M. Fukushima, pers. comm., see Figure 2 in the attached PDF). Growth rates observed for Sakhalin taimen inhabiting a brackish lagoon near the mouth of the Bekanbeushi River in eastern Hokkaido by Kawamura *et al*. (1983) is relatively low compared to the Russian populations, and is consistent with rates measured by Yamashiro (1965) within the same region. We compared these growth trajectories qualitatively to size at age based on scale back-calculations for 5 adults from Hokkaido's Shiribetsu River in western Hokkaido (H. Kawamura, Hokkaido Fish Hatchery, unpubl. data). Although the method used to generate this growth curve is not directly comparable to the methods applied to the other river populations, the general trajectory of growth for Shiribetsu taimen closely approximates growth for the faster growing, Russian populations. We decided to use the data from the Koppi River as the model for growth dynamics for the species given it is the largest set of data available, while acknowledging that it may not fully represent growth dynamics across the natural range of the species (particularly in eastern Hokkaido, as described above). Based on the parameter values derived for the Koppi River taimen, and assuming an average annual water temperature in the lower Koppi River of 10° C, we used the model of Pauly (1980) to estimate a rate of natural mortality (M) for the species of 0.11. We used this estimate of natural mortality to estimate L_{opt} (144 cm TL, the length class with the highest biomass for an unfished population) using the model of Beverton (1992). We then used the estimate of Lopt and the parameters from the von Bertalanffy growth model in the following formula to estimate generation time: -1.45 - ln(1- L_{opt}/L<SUBINF< sub>)/K. The resulting estimate for generation time was 14 yr.

Systems: Freshwater; Marine

- **Threats [top] Major Threat(s):**

Overfishing by various sectors (commercial, recreational, and illegal take) is one of the most important threats to this species. Although Sakhalin taimen are no longer commercially harvested in Russia, they are still targets of legal and illegal subsistence fishing as they are prized for their large size and good flavor (Zolotukhin *et al*. 2000). While reporting of taimen bycatch in the commercial pink salmon fishery in Russia has declined in recent years, we feel this is a result of under-reporting and a general decline in region-wide abundance of the species in recent years. These populations are also under threat from dramatic changes to their habitat expected from planned logging operations. An expanded logging lease in the Samarga River basin, for example, extends now to 85% of the total watershed area, with construction of roads that could greatly impact many key tributaries. Rapidly expanding oil and gas development on Sakhalin Island, in particular the laying of pipelines across more than 24 rivers known to support Sakhalin taimen, is posing a growing threat to the species. In Japan, land development (including river channelization, dam construction, agricultural and urban expansion) represents an important threat to critical habitat for the species. The threat from poaching in Russia, while hard to quantify, may currently be one of the most significant threats to the species. During a research trip in 2005, two active poaching camps were discovered, and five dead, adult taimen were recovered that had been captured using illegal fishing gear. Four of these individuals were mature females carrying as many as 15,000 eggs each (P.S. Rand, WSC unpubl. data). During spring peak flows, spawners tend to aggregate in side channels off the main stem of the river, and become vulnerable to capture by large mesh gill nets. Our estimate of fishing mortality in the river, although uncertain given the lack of data, suggests a relatively high rate of exploitation (~ two times the rate of natural mortality). Sustainable fishing rates on wild fish populations rarely exceed the rate of natural mortality. FAO (1999) recommends a precautionary approach in data poor fisheries by restricting fishing mortality to below the rate of natural mortality.

- **Conservation Actions [top] Conservation Actions:**

We feel the following measures need to be taken to stem further losses and allow recovery for the species:

1. We recommend expanding and/or modifying the network of conservation rivers designated by the government in Hokkaido to provide protection to Sakhalin taimen. The existing network was established originally for protection of commercial species (e.g. *Oncorhynchus masu* cherry salmon and *O. keta* chum salmon), and has been expanded in recent years to protect rare salmonids. However, a recent effort to identify prime habitat for Sakhalin taimen based on habitat modeling suggests the existing protected area network provides little protection for this species (Fukushima and Kameyama 2006). We strongly encourage the Hokkaido government to consider extending conservation river protection to the rivers identified by Fukushima and Kameyama (2006), particularly those in the Soya peninsula that still support healthy taimen populations.

2. We recommend new regulations on recreational fishing, particularly during the spawning season. While the species has been recognized as endangered ("red book species") in several regions (Primorye, Sakhalin and Hokkaido), the regulations triggered by these listings are not always sufficient or properly enforced (see #3). While establishing a ban on fishing is clearly needed in some circumstances, we think establishing exemptions in certain basins would be prudent if there is sufficient evidence that the exploited populations are stable or increasing. A key virtue of these exemptions is that the presence of recreational fishers, particularly in rivers in remote regions in the Russian part of the species range, could help deter illegal fishing practices. Where recreational fishing is allowed, we feel there should be a set of regulations enforced, including explicit creel limits and gear restrictions to reduce release mortality. These fish tend to become aggregated and vulnerable to heavy fishing pressure during the spring spawning season, so we feel it is especially important to enact regulations during this critical period in their life history.

3. We recommend increased enforcement of existing fishing regulations in the Russian part of the species range. Recent observations by research scientists have revealed illegal fishing operations, and much of the take, beginning in the 1980s and continuing to present, have gone unreported. Our observations have indicated that fisheries officers that are hired to enforce existing regulations have been ineffectual, largely due to a lack of presence on the rivers, particularly during the critical spawning period. We recommend increased vigilance to enforce fishing regulations intended to protect the species.

4. We recommend investigating the role of habitat and population fragmentation, particularly in Japan. Habitat fragmentation has been most widespread in Hokkaido, and we encourage actions that reduce and minimize further habitat loss, and restore habitat where possible. We are aware of ten individual, local efforts in Hokkaido to raise awareness of lost and degraded taimen habitat (e.g., Obirame Restoration Group), but we feel much more can be done through a broader scale assessment of salmonid species diversity, threats, and cumulative aquatic habitat loss across Hokkaido. A formal investigation by key public agencies into how to better balance flood plain development with conservation of rare species is critically important. A key step has recently been taken to form the Committee of Critically Endangered Species (CCES) by the Hokkaido government, and we encourage this group to focus on habitat related issues involving conservation of Sakhalin taimen.

5. We recommend formulating and enforcing best practices for infrastructure development, particularly related to resource extractive industries. While much of the habitat for Sakhalin taimen in Russia is intact, there are a number of threats that exist. Logging, road construction and pipeline development present threats to spawning habitat, in the form of increased bank instability, leading to accelerated erosion and sedimentation. Road construction also leads to increased illegal fishing activities by providing easier access to rivers. Sound best practices (e.g., riparian buffers, pipeline river crossings, culvert designs) need to be established and enforced to reduce erosion and allow unimpeded movement of fish throughout the watershed.

6. While there has been some preliminary efforts in both Japan and Russia at captive

breeding for the species, we feel these activities should proceed with great caution. Inter-basin transplants could contribute to loss of locally adapted gene complexes. We encourage basic research on the degree of geneflow that exists between river populations to understand phylogeographic patterns that could help guide future reintroductions. Although there is some evidence that captive propagation can help reduce short-term extinction risk for critically endangered species, there is virtually no empirical evidence to indicate whether propagation can promote long-term sustainability. Therefore, captive propagation efforts, to the extent that they exist, are at best stop-gap measures and are in no way a substitute for conserving the species in the wild.

7. Finally, given the myriad threats to the species, it's dramatic rate of decline, and it's cross border, limited distribution, we feel it is important to establish an intergovernmental working group to consider formally our proposed conservation actions and draft an implementation plan to conserve the species.