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Review of Relationships between Lost River and Shortnose Sucker Biology and Management of Upper Klamath Lake

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Abstract (timeline)

Historically, Lost River (LRS) and shortnose suckers (SNS) were abundant in Upper Klamath Lake and were utilized as a subsistence fishery by the Klamath Tribe. In the 1900s, the suckers, known locally as "mullet," were subjected to a snag fishery on spawning adults. The fishery became increasingly more regulated, first by making them "game species" under Oregon statute in 1959, followed by bag limits in 1969, and closure of the fishery in 1987. Over the period from 1966 to 1986, the annual harvest of fish declined 95 percent from about 12,500 to 687 fish and several spawning groups went extinct.

In 1988, both species were listed as federally endangered and the Williamson/ Sprague runs were estimated at less than 12,000 LRS and less than 3,000 SNS. After listing, monitoring programs shifted from fishery-based to non-fishery based. By the time of the 1992 Biological Opinion (BiOp) for the Klamath Project, managers operated under assumptions that adult populations and recruitment were low but a major source of adult mortality, the fishery, had been controlled. Factors responsible for the decline of these species were thought to include "the damming of rivers, dredging and draining of marshes, instream flow diversions, over-harvest, introductions of nonnative fish, and a shift toward hypereutrophication and poor water quality in Upper Klamath Lake and waters downstream" (1992 BiOp). Because both species are long-lived and highly fecund (produce large numbers of eggs), it was thought, "Infrequent gaps in recruitment will not adversely affect healthy populations," but because of inconsistent recruitment (new young spawners) and poor age structure (large numbers of year classes with zero fish), the 1992 BiOp did not allow for more than 2 consecutive years of low water (a minimum surface elevation as low as 4,137.0 feet through September 30). Low lake elevation was thought to reduce necessary larval and juvenile shoreline habitats and was assumed to equate with low recruitment. A low lake elevation of 4,139.0 feet was thought adequate to "provide suitable habitat for the maintenance and enhancement of sucker populations and will improve the chances of reaching the spring spawning water level."

Bureau of Reclamation recovery actions in the 1990s focused on marsh and spawning site reclamation, salvage of diverted suckers from irrigation ditches, and research to better understand sucker biology, dams, and lake water quality and quantity. Two contrasting events during the 1990s were the production of several apparently good year classes (1991, 1993, 1995, and 1999) and the significant loss of adults in three consecutive fish kills (1995–1997). The size of each fish kill easily equaled the annual size of the fishery in the 1960–1980s and the 1996 and

1997 fish kills were certainly much larger. Although data from the early 1990s appeared to indicate rebounding adult populations, by the time of the 2001 BiOp, managers' assumptions about the populations were largely the same as in 1992 except that a source of adult mortality—fish kills—was clearly not under control. In response to generally low juvenile recruitment and adult fish kills of the previous decade, the decision in the 2001 BiOp was to raise the minimum lake elevation from 4,139 to 4,140 ft. The cornerstones of the 2001 Biological Opinion were: 1) a Congressional mandate to err on the side of the species of concern in the face of uncertainty; 2) a failure of the Bureau of Reclamation to implement certain requirements of prior BiOps; 3) increased imperilment of the species since 1992; and 4) an increased concern for the effects of poor water quality. The mix of relevant factors in 2001—poor water quality, adult fish kills, and adult populations perhaps at similar levels as 1992—suggested that there was uncertainty in the response of these populations to the actions taken since 1992. Managers acknowledged that lake elevation alone could not guarantee recruitment and healthy adults, but argued that elevations as low as 4,137 ft could pose significant risk and elevation targets of 4,139 ft had had uncertain benefits in the previous decade. Thus, in the face of uncertainty, the decision was made to raise the minimum elevation to 4,140 ft.

Introduction

Lost River (LRS) and shortnose (SNS) suckers became federally listed endangered species in 1988 but concern for their declining abundance had been raised by OSU Professor, Carl Bond, and others in the 1960s. In 1983, the Klamath Tribe, Oregon Department of Fish & Wildlife (ODFW), and U.S. Fish and Wildlife Service (USFWS) initiated a study of Klamath suckers (Bienz and Ziller 1987). These studies discovered populations composed of older fish (95 percent of LRS were more than 19 yrs old) and prompted the Klamath Tribe to curtail sucker fishing in 1985 and the State of Oregon to close the fishery in 1987 (Scoppettone and Vinyard 1991). An additional cause for concern was water quality, primarily high nutrient loads (phosphorus and nitrogen) and associated blooms of blue green alga (*Aphanizomenon flos-aquae*), high pH, and low dissolved oxygen (Vincent 1968). More recently, researchers have documented additional loss of spawning populations, large fish kills, fluctuating abundance, variable recruitment of juveniles, simplification of the age/size structure through loss of older fish and the success of non-native fish. The concern for water quality has expanded to include other anthropogenic (human-caused) changes in Upper Klamath Basin, including water diversions and loss of floodplain, wetland, and riparian habitats. The USFWS considers these species to be at unacceptably high risk of extinction (USFWS 1993, 2001). Because a federal agency, U.S. Bureau of Reclamation (USBR), manages the release of water from the habitat of endangered species (Upper Klamath Lake, see Policy chapter), section 7 of the Endangered Species Act requires that USFWS and USBR ensure that the Klamath Project does not jeopardize those species.

In the following we provide background information on aspects of sucker life history, demographics, and physiological tolerances in order to understand both the threats to their existence and the logic behind management and recovery efforts. We relate monthly elevations of Upper Klamath Lake to biological processes and compare the USFWS 2001 Biological Opinion (2001 BiOp) with the 1992 BiOp.

Sucker biology background

Both suckers are long-lived, up to 43 yr (LRS) and 33 yr (SNS), with a reproductive lifespan for females beginning at 7–9 yr (LRS) and 6–7 yr (SNS). Females produce 70,000–200,000+ eggs per spawning season. Beuttner and Scoppettone (1990) and Perkins et al. (1998) found evidence that larger suckers produce more gametes (eggs and sperm) but it is not known whether gametes improve in quality as adult size increases, a common pattern in other fishes (Sinclair 1988). Females may not spawn every year. They may, for example, skip years if energy reserves are low, if they have been significantly stressed, or if environmental conditions are not appropriate, but this suspicion is difficult to document. Suckers are iteroparous (an individual spawns in many years). The advantage of the long-lived, iteroparous strategy is that an individual's progeny production is spread over many years, increasing the likelihood of spawning when environmental conditions are favorable for progeny survival, thereby reducing the impact of environmental variation on lifetime reproductive success (Leaman and Beamish 1984; Goodman 1984; Schultz 1989). Such a strategy benefits from a broad distribution of spawning age classes because there is greater reproduction from older fish and because different-aged fish tend to spawn at different times during the season, thus extending the annual spawning season within a year, again spreading risk over time.

While longevity compensates for varying environmental conditions, it also makes fish more susceptible to over-exploitation. The removal of larger fish through fishing mortality can be detrimental to long-lived species, especially when the fishery targets large spawning fish. Because they are iteroparous, individuals are subjected to mortality every year they spawn and the probability of reaching old age is reduced. The result is lowered egg production and truncation of the upper end of the age distribution of spawners and their potentially higher reproductive potential (Borisov 1978; Beverton 1986; Leaman and Beamish 1984).

In Upper Klamath Lake, tagging studies suggest suckers spawn either in lakeshore springs or in the Willamson and Sprague rivers and seldom mix between these spawning sites. Perkins et al. (1998) and USGS (2001) have reported recapture of 446 suckers at lakeshore springs, and only 1 had been originally tagged in an area away from the springs. USGS (2000) reports recapture of 119 Lost River suckers at lakeshore springs; 118 had been tagged at the springs and 1 in the Williamson River. The same effort recaptured four previously tagged shortnose suckers, all of which were recaptured at the original tagging location. Fish movement among eastern lakeshore springs has been observed. USGS (2001) reports a total of 69 suckers (63 Lost River suckers and 6 shortnose suckers) were captured at least twice in 2000 at shoreline spawning areas. Of the 63 Lost River suckers, 48 percent were recaptured at springs other than where they were first captured, and 5 out of 7 shortnose suckers were captured at sites other than where they were tagged. However, it has not been documented that suckers actually spawn at multiple locations. Capture at different springs demonstrates movement and is suggestive, but does not conclusively prove lack of reproductive isolation between spawners at different lakeshore springs.

At this time, genetic and size distribution data are inconclusive as to whether in-lake and river spawning groups are reproductively isolated or broadly mixing (panmictic). For example, different sizes of spawners might indicate that spawning groups are not randomly drawn from the whole population but are reproductively isolated. Perkins et al. (1998) found larger LRS at lake springs relative to con-specifics in the river, except in 1998. USGS (2001, Table 2) suggests median size differences between river and lake spawning suckers are minimal, but more recent analyses suggest LRS at lake shore springs are larger than con-specifics at other locations (Rip Shively, USGS personal communication). Genetic data collected to date cannot discriminate between lake and river spawners (unpublished data).

It also is not known whether progeny also display fidelity to natal sites (i.e., are imprinted and have homing ability) and therefore, whether spawning groups are self-maintaining or part of a panmictic population created by intergenerational mixing (river progeny recruiting to in-lake springs or vice versa). The presence or absence of spawning site fidelity is an important question because high fidelity effectively limits natural recolonization of suitable sites. Also, multiple spawning sites may offer greater protection from chance events than a single site of comparable area. Thus, loss of high-fidelity spawning groups (if that is the life history strategy of these species) could lower total production beyond the simple loss of adult numbers and reduce the "buffer" provided by multiple sites.

The strategy of producing large numbers of small eggs means that there usually is high mortality in the early life of most fishes. Average patterns of freshwater fish mortality suggest 95 percent do not reach the juvenile stage (Houde 1994). Field work done in 1989 indicates apparent larval mortality rates within the Williamson River were 93 percent per day (Larry Dunsmoor, Klamath Tribe, personal communication). Cooperman and Markle (1999 and unpublished data) documented that larval sucker movement through the Williamson River can take as little as 1 day, and that greater than 99 percent of larvae exit the Williamson before completing flexion (caudal fin formation). This suggests that the 93 percent mortality level calculated by Dunsmoor is reached within the first days of the larval life history stage, a developmental stage that lasts approximately 40–50 days. Simon and Markle (2001) showed annual October population estimates of juveniles (1995–2000) ranged from 0 to 108,000 for LRS and about 1,500 to 74,000 for SNS. They also suggested that winter mortality (winter kill) might routinely reduce young-of-the-year abundance an additional 90 percent by the following spring. Because mortality rates are high for a relatively long time, very small changes in rates or duration can lead to dramatically different outcomes (Houde 1987). Fisheries scientists are seldom able to measure these rates with the precision needed to detect small changes and thus have difficulty determining causes of annual differences in year-class production. Despite this, it is clear from the following studies that acute environmental conditions (primarily water quantity, water quality, and other organisms) can adversely affect the numbers of young and older suckers.

Sucker distribution and habitat use change throughout the life cycle. Eggs are deposited in unconsolidated gravel/cobble bottoms in areas of ground water upwelling or in portions of rivers 2–6 ft deep with moderate current. Larval suckers are most abundant in near-shore areas of northeast UKL and the lower Williamson River. Larvae are associated with macrophytes (large non-woody plants), particularly emergent macrophytes (those partly above the water surface) such as *Scirpus acutus* (hardstem bullrush), *Sparghanium eurycarpum* (river burr reed), and *Polygonum coccineum* (water smartweed). During summer, the daytime habitat of age-0 juveniles shifts to include both emergent macrophytes and near-shore clean rocky substrates (sand, gravel, small boulders) but not fine silty bottoms (Simon et al. 2000). Also during summer, the center of abundance of age-0 juveniles moves southward in the lake, perhaps associated with the distribution of preferred gravel substrates. By fall, juveniles are no longer associated with near-shore habitats and move offshore to deeper waters where all substrates are fine silts. Older juveniles and adult suckers are found through out UKL, but are concentrated in the northern third of the lake (Reiser et al. 2001).

In Upper Klamath Lake, lake elevation is highly autocorrelated and cross-correlated with other variables of interest. For example, because of lake management and seasonal hydrological cyles, August 15 elevations are highly autocorrelated with elevations on earlier dates. Similarly, temperatures and other important water quality variables are highly correlated with dates, as are lake elevations, thus leading to complex cross-correlations. Thus, it is important to understand that simple relationships between suckers and lake elevations may not relate only to water quantity. Over the past decade, juvenile abundance has been monitored in late summer. Since 1995, the effort has used a stratified random design to calculate a September index of year-class strength (Simon et al. 2000). Despite using different methodologies in 1991–1994, a September year-class strength index can be estimated for 1991 through 1994 based on the number of individuals caught adjusted by the effort used to catch them (catch per unit effort, CPUE). When September year-class strength indices are arranged by July 15 lake elevation, it is clear that there is a relationship with water quantity (Figures 1 and 2). When lake elevation exceeds 4,141.7 on July 15, the average LRS index is about two times higher than at lower elevations, and four times higher for SNS. The result is a probability distribution—higher lake elevations are more likely to produce higher indices but are not guaranteed to do so. For example, there are low water years (1991) when year-class strength was strong and high water years (1998) when year-class strength was poor. Those unusual observations do not negate the pattern, but do suggest that factors other than lake elevation are important. This is similar to the situation when climatologists tell us we are in a wet climactic cycle and we experience a year that is drier than during dry cycles.

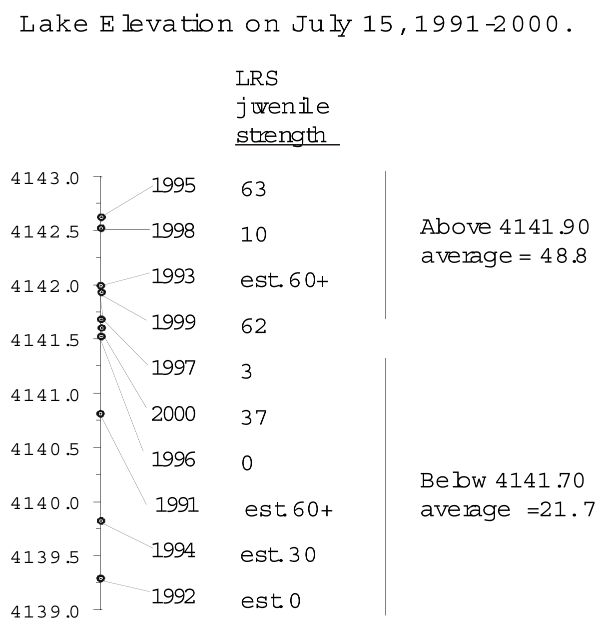


Figure 1. Relationship between Upper Klamath Lake elevation on July 15 and Lost River sucker September juvenile year class strength (Simon et al. 2000). Years 1991–1994 estimated based on fixed cast net and trawl catch per unit effort data.

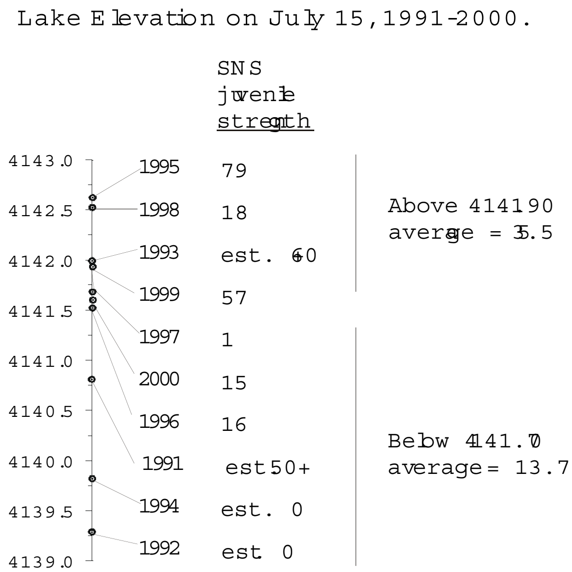


Figure 2. Relationship between Upper Klamath Lake elevation on July 15 and shortnose sucker September juvenile year class strength (Simon et al. 2000). Years 1991–1994 estimated based on fixed cast net and trawl catch per unit effort data.

Some water quality parameters (temperature, pH, dissolved oxygen, and unionized ammonia) frequently reach levels stressful to suckers (Loftus 2000). Lethal effects of water quality on Klamath suckers have been examined in multiple laboratory tolerance studies (Falter and Cech 1991; Castleberry and Cech 1992; Monda and Saiki 1993; Bellerud and Saiki 1995; Saiki et al. 1999). All studies report similar findings. Saiki et al. (1999) found concentrations required to kill at least 50 percent of larvae or juveniles in 96 hr tests were temperatures of 30.3–31.8 C, 0.5–1.1 mg/l ammonia, 10.3–10.4 pH, and 1.3–2.1 mg/l DO. Meyer et al. (2000) examined 14- and 30-day chronic effects and found mortality thresholds from 0.37–0.69 mg/l ammonia, >10 pH, and 1.5–2.0 mg/l DO. In support of the lab studies, positive daytime field collections of juveniles have seldom been associated with these lethal conditions (Simon and Markle 2001 and earlier reports). Poor water quality also may exert a significant indirect effect. Adult fish kills in 1995, 1996, and 1997 were caused by *Flavobacterium columnare*, an opportunistic bacterial infection that is always present but which causes death only when fish are stressed by low oxygen, high pH, warm temperatures, and/or high unionized ammonia. In contrast, Terwilliger et al. (MS) could find no indirect effects of poor water quality on juvenile growth, even during a year of excessively high unionized ammonia levels (1997). They suggest that surviving juveniles may have found water quality refugia.

The fish community of the Klamath Basin has changed in the past century with unknown consequences. Scoppettone (1991) reported 84.5 percent of the fish biomass in UKL is exotic species, and Logan and Markle (1993) reported that exotic fishes were 58 percent of the fish captured in trap nets in Agency Lake and the northern portion of Upper Klamath Lake and 92 percent of the beach seine fish fauna. Fathead minnows represented 59 percent of the fish in trap net samples in Agency Lake and 27 percent in Upper Klamath Lake in 1992 (Simon and Markle 1997). The latter also reported that declines in fathead minnow abundance from 1991–1995 were associated with an increase in some native fishes. Since 1995, patterns have been more complex. In 1998, the year following the 1995–1997 fish kills, beach seine catch rates dropped for age 0 native fishes (suckers, blue chub, and tui chub) but rose for exotic age 0 yellow perch and were unchanged for fathead minnows (Simon and Markle, 2001). Fathead minnows prey on larval suckers in a laboratory setting (L. Dunsmoor, Klamath Tribe, unpublished report) and young yellow perch are known to be opportunistic fish eaters (Hubbs and Lagler 1974). The impacts of exotic species on sucker larvae are unknown, but it has been suggested that management actions enhancing habitat availability or water quality for the benefit of suckers could also have positive effects for exotic species.

Status of endangered suckers

Because the species were poorly studied, the initial cause of concern was declining catches in a popular seasonal snag fishery and elimination of some of those fisheries (Andreasen 1975). Klamath suckers were game fish by Oregon statute and in 1969, Oregon Department of Fish and Wildlife (ODFW) instituted a bag limit of 10 suckers (locally referred to as “mullet”). The “mullet” fishery on Klamath suckers was extremely popular. It was of historical importance to the Klamath Tribe as well as to the rest of the community. The first reference to sport fishing of “mullet” appears to be a 1909 reference to sportsmen snagging “mullet” in the Link River at Klamath Falls (Klamath Republican, Oct. 14, 1909). In the 1960s ODFW’s Klamath Falls office maintained a mailing list of mullet fishermen from Seattle to Los Angeles who were sent a postcard informing them of the timing of the sucker runs. They harvested an estimated 100,000 lbs in 1966 (ca. 12,500 fish) according to ODFW’s Art Gerlach (*Eugene Register-Guard*, May 7, 1967). From 1966 through 1978, ODFW data files show a decline from 3.5–5.6 suckers per fisher before the 1969 bag limit, to 1.5–3.0 suckers per fisher afterwards. From 1966 to 1974, average lengths declined from 25.7 in to 21.3 in, average weight declined from 7.54 lb to 4.9 lb, and number of fish caught per hour declined from 1.19 to 0.87. The decline in catch rate continued through 1986 (Fig. 3).

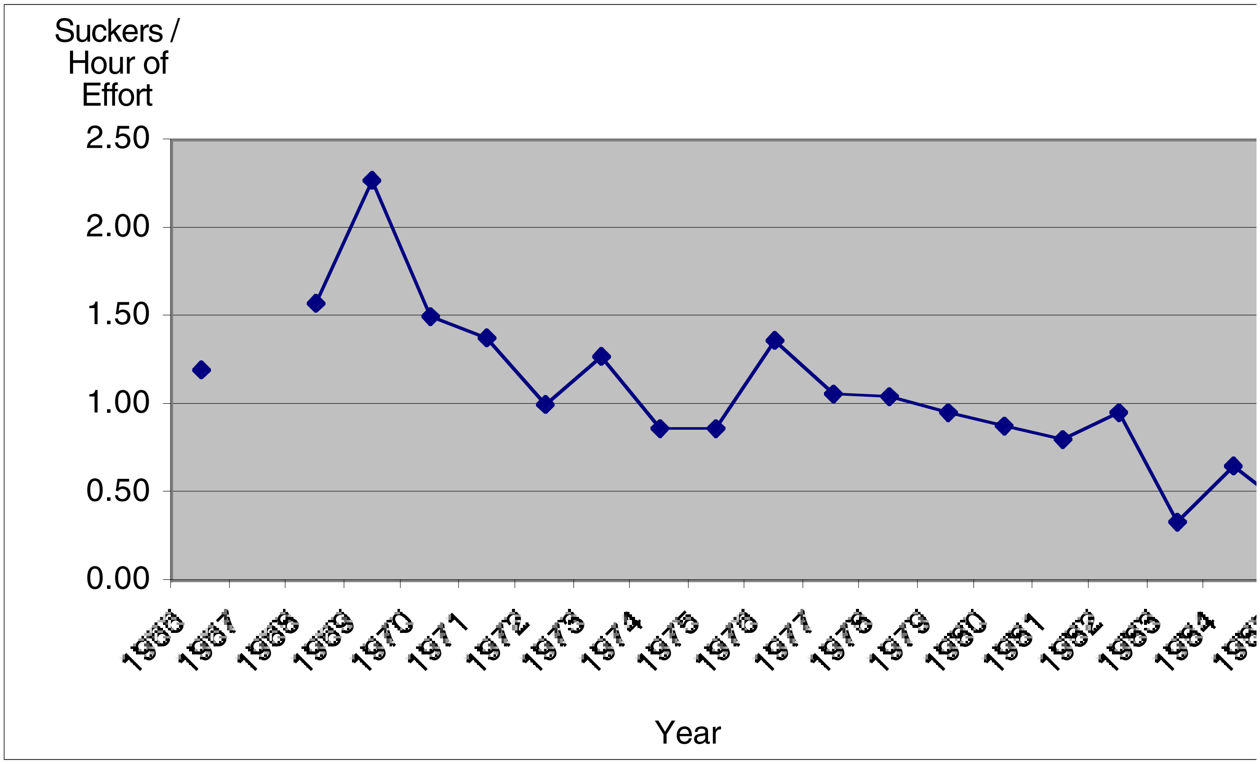


Figure 3. Relationship between sucker catch rate and year (data before 1974 also reproduced in Andreasen 1975).

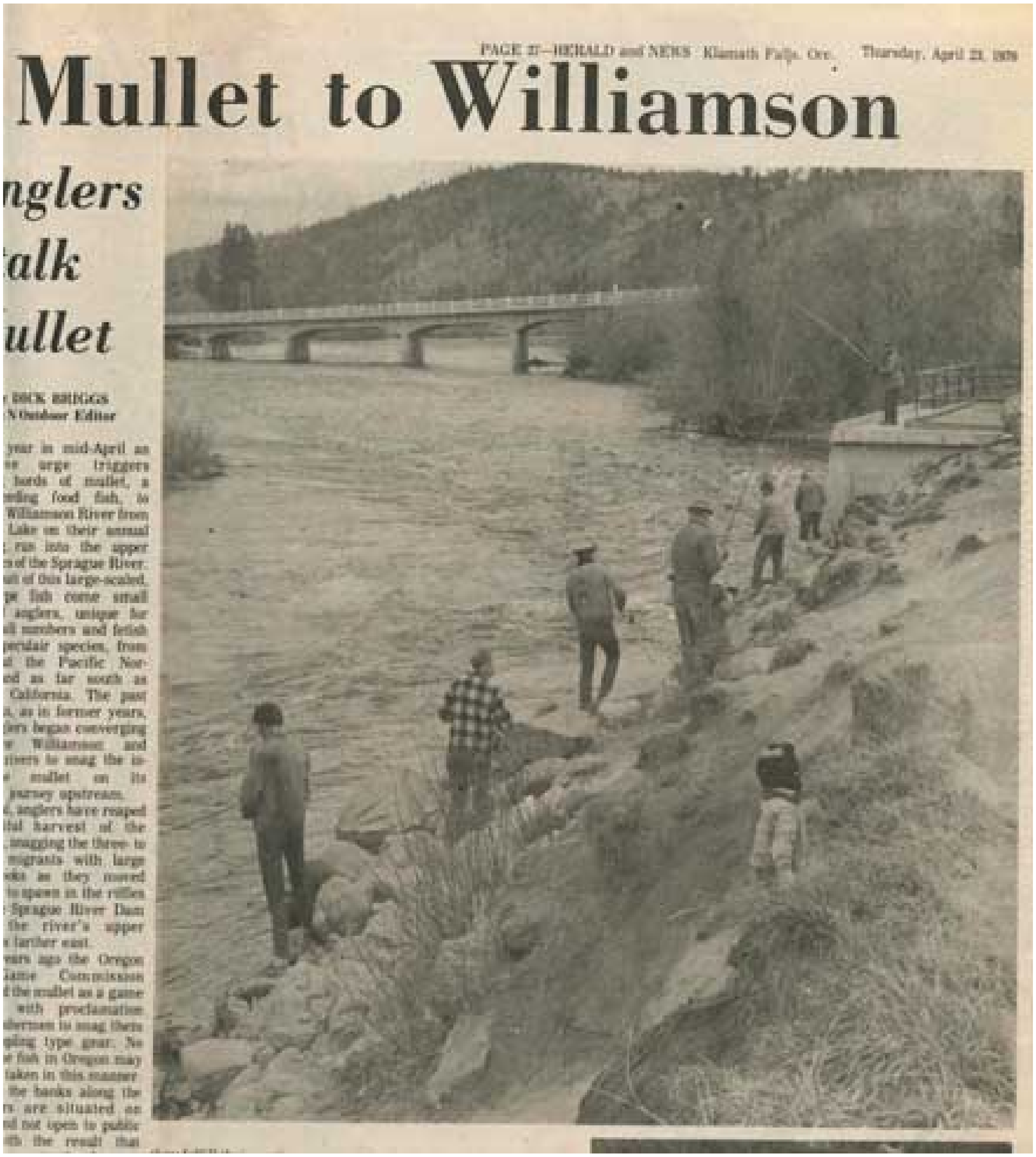
In 1984 and 1985, Bienz and Ziller (1987) estimated the harvest had dropped to 1,262 and 687 fish, respectively, and 92 percent of the 1985 catch was LRS. Thus, in 19 years the catch had dropped about 95 percent from about 12,500 fish to 687. This decline may be understated since ODFW files indicate undersized fish were often discarded and not counted in the 1960–1970s.

The "mullet" fishery was a snag fishery in which anglers used treble hooks weighted with sparkplugs to snag large spawning fish (Figures 3 & 4). There is direct and indirect evidence that the fishery may have contributed to elimination of several spawning groups. During the record-low lake elevations of 1994, Oregon State University researchers mapped shoreline substrates, including the distribution of sparkplugs and treble hooks. Many sites with sparkplugs, such as Ouxy and Sucker Springs, are known sucker spawning sites, but at least four other areas on the eastern shore between Modoc Point and Sucker Springs had treble hooks and spark plugs, as well as flowing springs, suggesting historical sucker spawning (unpublished data).

Numerous other locations are thought to have lost sucker spawning groups in the past 20–-30 years. The last spawning fish were seen at Harriman Springs on the west side of the lake in 1974 (Andreasen 1975) and no spawning has been observed at Barkley Springs on the southeast side of the lake since the late 1970s (Perkins et al. 1998), where extensive habitat modifications limiting access to the spring is thought to have caused extirpation. More than 90 springs were mapped on Bare Island in 1994, many with water too hot (>30C) for spawning, but spawning suckers were reported at a Bare Island spring in the early 1990s, an observation unconfirmed based on surveys in 1997 (Perkins et al. 1998) and 2001 (R. Shively, USGS, personal communication). In Agency Lake sub-basin, sucker spawning was last documented in

Crooked Cr. in 1987 (R. Smith, ODFW, personal observation) and in Fort Cr., Seven Mile Cr., Four Mile Cr., Crystal Cr., and Odessa Springs in the late 1980s and early 1990s. The Wood River may have the last spawning suckers in this subbasin, based on recent captures of a few adult SNS and capture of larvae in 1992 (Markle and Simon 1993; Simon and Markle 1997). In addition, annual monitoring of larval and juvenile suckers in Agency Lake has shown a long-term decline in the 1990s, with only two juveniles caught in 2000 and one juvenile caught in 2001 (Simon and Markle, 2001).

Figure 4. A 1967 “muleteer”, Ken Mills showing catch with spark plug/ treble hook snagging gear (Eugene Register Guard, May 7, 1967)


PAGE 27—HERALD and NEWS Klamath Falls, Ore. Thursday, April 23, 1970

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BICK BRIGGS
N Outdoor Editor

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Figure 5. Sucker fishers below Highway 97 bridge on Williamson R. (*Klamath Falls Herald and News*, Apr. 23, 1970.)

Several attempts have been made to estimate the size and age structure of sucker populations in UKL (Bienz and Ziller 1987; USFWS 2001). Confidence intervals are large, methodologies differ, and interpretation of these numbers should be cautious. At an order-of-magnitude scale, all of the estimates suggest adult populations between 1984 and 1997 are measured in the low thousands to low 100 thousands. The populations that sustained the fishery in the 1960s and earlier were almost certainly larger. Because there are no reliable long-term adult abundance data, managers have relied on indices. For example, a Williamson River spawning abundance index has been downward since 1995 (Figure 6). This decline was especially disturbing because it coincided with the time when the relatively strong 1991 and 1993 year classes would have been expected to begin spawning.

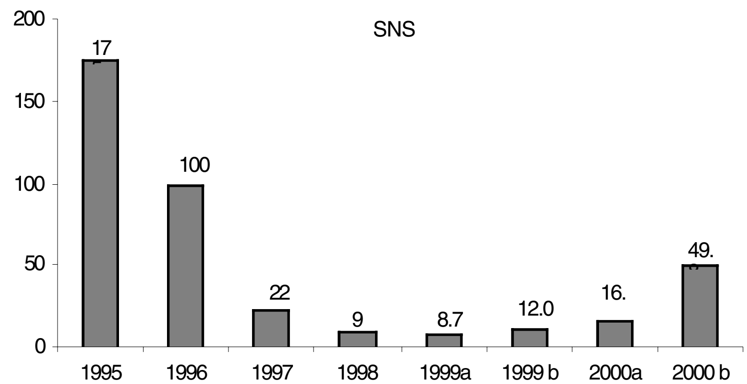

Figure 6. Population index trends in Williamson River spawning runs, 1995–2000 (USGS 2001).

The number of fish killed during the 1995–1997 fish kills is also uncertain, but the numbers collected give some idea of the magnitude of these events. The numbers of dead suckers collected during each fish kill event were 472 (1995), 4,453 (1996), and 2,335 (1997) (Perkins et al., 2000). Collections were not systematic and involved different levels of effort, making interannual comparisons difficult. If the numbers collected are considered minimum estimates, they suggest that the fish kills were at least the same order of magnitude as the snag fishery in the early 1980s and probably as large as or much larger than earlier snag fisheries. The lack of long-term adult abundance data and quantifiable fish kill data is a major data gap.

In the 1980s, the populations in UKL appeared limited by lack of juvenile recruitment and were heavily skewed to older fish, 19–28 yrs (Buettner and Scoppettone 1990; Scoppettone and Vinyard 1991). In the late1990s, successful recruitment from 1991 and 1993 year classes brought in some younger fish (Cunningham and Shively 2000; USFWS 2001), but many older fish appear to have died prematurely, probably because of the fish kills in 1995, 1996, and 1997. Based on lengths of suckers entering the Williamson River in 2000 (Cunningham and Shivley 2001) and ages estimated from a size/age relationship (Buettner and Scoppettone 1990), LRS spawners were 5–35 yrs. and SNS spawners 4–27 yrs with median ages of about 12 yrs (LRS) and 9 yrs (SNS). The ranges and median ages suggest that most of the fish were produced after closure of the fishery. Coupled with the apparent declining adult abundance, the shift in age structure to younger fish means that reproductive potential declined. For example, the loss of large old fish during the fish kills means that even if the adult populations in 1992 and 2001 were the same size, the reproductive potential would have been lower in 2001.

Criteria date-specific monthly elevations of Upper Klamath Lake

The 2001 BiOp (Section III, Part 2, pages 143–145) provides date-specific minimum elevations for UKL and justification (Table 2). Five criteria are presented for minimum lake elevation guidelines; winter-kill, shore-line spawning, young-of-year habitat, water quality, and access to refugia. Each criterion is discussed below.

Table 2. Mandated date-specific minimum levels for UKL and justifications.

Date	Minimum level	Justification criteria
Jan 1	4,141.0	• Reduce potential of winter-kill • Water depth for shore-line spawning
Feb 15	4,141.5	• Water depth for shore-line spawning • Reduce potential of winter-kill
Mar 15	4,142.0	• Water depth for shore-line spawning • Reduce potential of winter-kill
Apr 15	4,142.5	• Water depth for shore-line spawning • Inundated emergent vegetation for y-o-y habitat
June 1	4,142.5	• Inundated emergent vegetation for y-o-y habitat • Moderate water quality
Jul 15	4,141.5	• Inundated emergent vegetation for y-o-y habitat • Moderate water quality • Access to refugia
Aug 15	4,141.0	• Inundated emergent vegetation for y-o-y habitat • Moderate water quality • Access to refugia
Sep 15	4,140.5	• Moderate water quality • Access to refugia
Oct 15	4,140.0	• Moderate water quality • Access to refugia • Reduce potential of winter-kill

Winter kill

"Winter kill" is mass mortality of fishes during winter, usually associated with low dissolved oxygen levels caused by ice cover, which prevents wind-generated re-oxygenation of water. Following ice cover, additional oxygen comes only from photosynthesis, which is also low in winter. Snow on top of ice may exacerbate conditions by further reducing light penetration and photosynthesis. At any given initial concentration, the total amount of dissolved oxygen is a function of volume, thus higher lake elevations equate to more available oxygen.

The rate at which oxygen is removed from water is a function of the biological oxygen demand (BOD, resulting from respiration of living organisms such as bacteria, plants, and fish) and chemical oxygen demand (COD, the reaction of chemicals with oxygen). In UKL, BOD is thought to be notably greater than COD and bacterial decomposition is typically the greatest BOD component.

A fish's vulnerability to winter kill is dependent on many factors, including species and life stage, physiological condition, and severity of the winter. Documenting winter-kill is difficult and has not been documented in Upper Klamath Lake suckers. Simon and Markle (2001) hypothesized that winter kill may occur in Upper Klamath Lake since several species, including juvenile suckers decline by about 90 percent in abundance between late fall and early spring. The 2001 BiOp (page 192) addresses the potential interaction between lake level and winter kill, "there is a higher probability of low DO at lower elevations.…Welch and Burke (2001) estimated…that DO levels would be adverse to suckers after 60 days of ice cover or less. To reduce the risk of catastrophic winter fish kills, they recommended that UKL end of season levels should not go below 4,140 ft and be brought up quickly."

Shore-line spawning

Because there is evidence of loss of in-lake spawning groups, maintaining viable lake-shore spawning is a primary management concern. Lake-shore spawning typically extends from February to May with most in March and April (USGS 2001). Both the number of sites and total surface area for lake-shore spawning is directly related to lake elevation. Surveys of Sucker Springs found >60 percent of spawning was in water greater than 2 ft deep, leading Reiser et al. (2000) to suggest minimum acceptable water depth during spawning season should be 2 ft above lake shore springs. The relationship between lake elevation and percent of spawning habitat at two important eastern shore springs shows 13–45 percent of the spawning substrates will be > 2 ft deep during March and April if the 2001 BiOp elevations are met (Table 3). These elevations equal the pre –Link River dam (1921) elevations for February and March but are 0.44 ft higher than pre-1921 April elevation of 4,142.06 ft (Figs. 7 & 8). The 2001 BA requested lower levels (Fig. 8).

Table 3. Relationship between 2001 BiOp minimum lake elevation (ft above mean sea level (MSL)) and percent of spawning habitat at two important eastern shore springs (from Reiser et al. 2001).

Date	Lake elevation	Potential habitat, % > 2 ft deep	
		Sucker Springs	Ouxy Springs
Feb 15	4,141.5	5	0
Mar 15	4,142.0	27	13
Apr 15	4,142.5	45	33

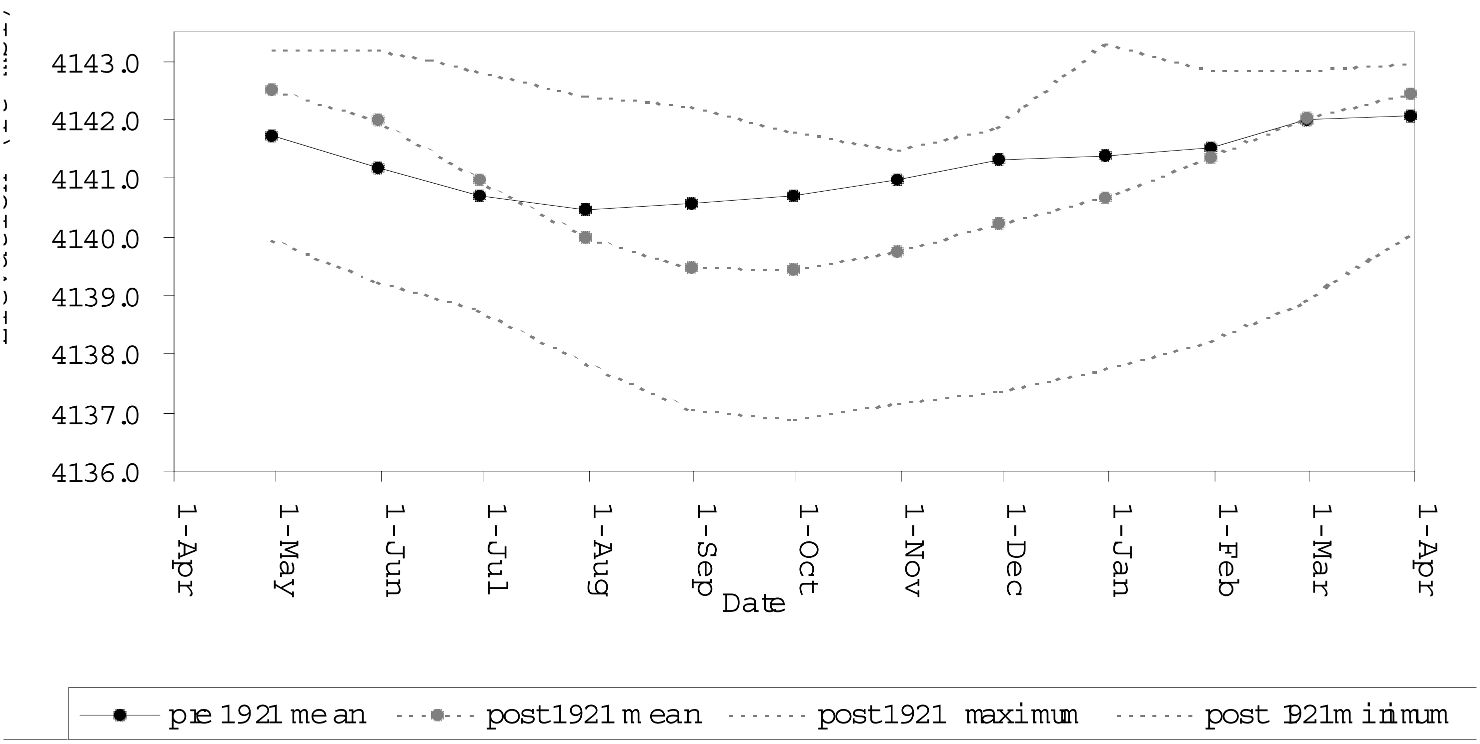

Figure 7. Relationships between lake elevation and month before 1921 and after 1921. Outer dotted lines show total range of variation since 1921.

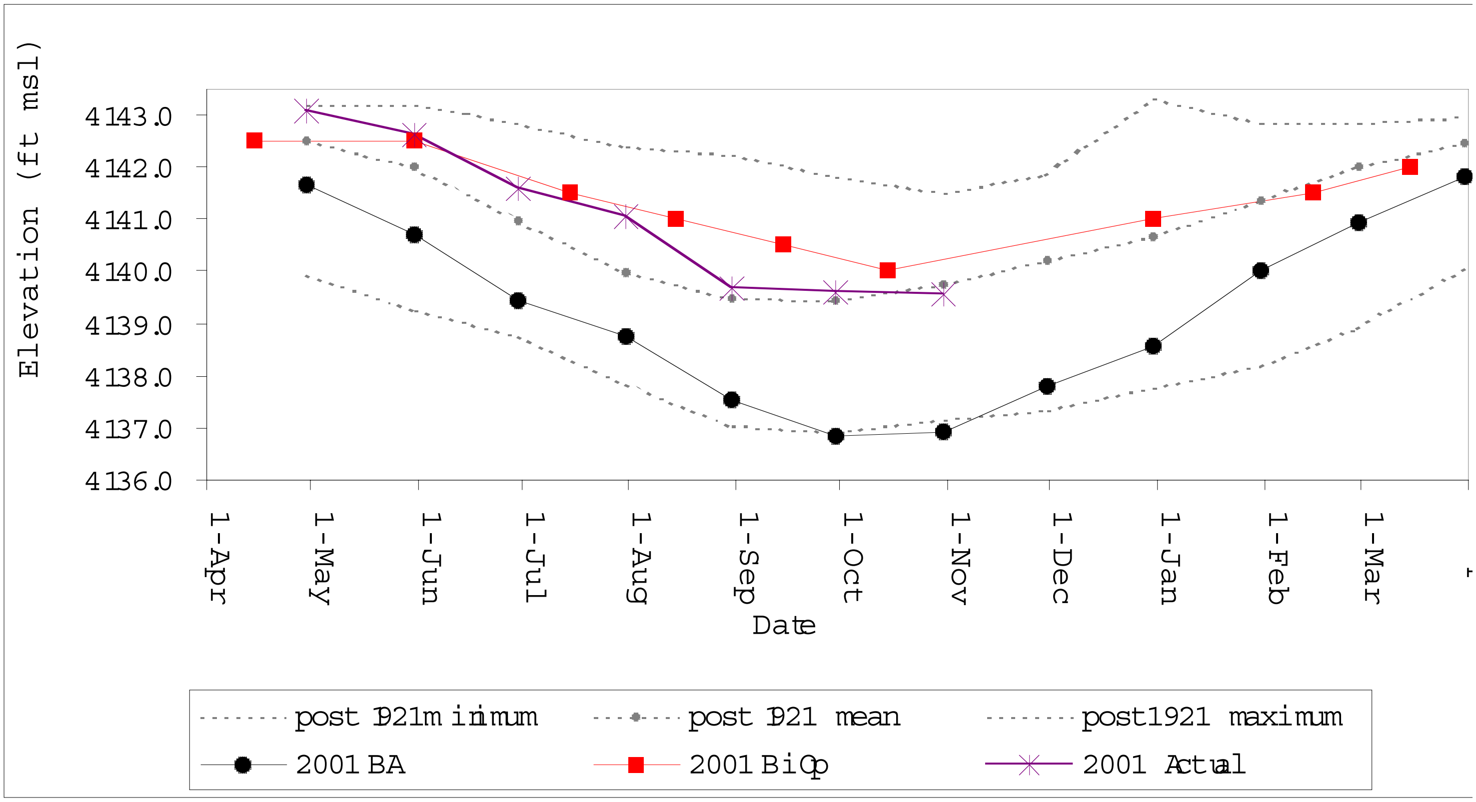

Figure 8. Lake elevations as suggested by the 2001 BiOp, 2001 BA, and actual 2001elevations as permitted with the coho amendment. Dashed lines show mean, minimum, and maximum monthly values since 1921 as in Fig. 7.

Young-of-the-Year habitat

"Young-of-the-Year" (YOY) or "age-0" refers to fish after hatching and before completion of their first winter. YOY suckers typically range from 10 to 75 mm, though LRS may reach 100 mm in years with good growth rates. YOY suckers are subdivided into larval and juvenile stages. Larval suckers typically are in the Williamson River-UKL system from March thru June and juveniles after April. The mouth of the Williamson River and Goose Bay are two areas known to have high concentrations of larval and juvenile suckers and are considered critical rearing grounds. Larval suckers are associated with emergent macrophytes around the periphery of the lake and the edges of the Williamson River. The volume of emergent macrophyte habitat potentially available to young suckers is a function of lake elevation, such that less than 10 percent of emergent macrophytes around the lake periphery are are under 1 foot of water at 4,140 ft, 10–25 percent at 4,141.0, 40–60 percent at 4,142.0 and 85–100 percent at 4,143.0 ft (Reiser et al. 2001). During the time frame YOY suckers are present, the lake levels required by the 2001 BiOp results in availability of about 70 percent of the emergent macrophytes near the mouth of the Williamson River to a minimum of about 5 percent in the Williamson River and Goose Bay.

The relationship between lake elevation and YOY production does not appear to be simple or linear. The minimum elevation set for July 15, 2001 (target—4,141.5 ft, actual 4,141.43 ft) was the fourth-lowest since 1991. Of the 3 years when elevations were lower, a juvenile strength index was zero in 1992 and 1994, when July 15 lake elevations were 4,139.29

ft and 4,139.87 ft, respectively (Figs. 1 & 2). However, in the other low water year, 1991, very good year-classes were produced with a July 15 elevation of 4,140.81 ft. Years with higher lake elevations produce better year classes on average (Figs 1 & 2). These patterns suggest that the 2001 elevation would be expected to produce a poor year-class and preliminary calculations confirm year-class strength for SNS and LRS will be low (Simon and Markle, Oregon State University, unpublished data).

Water quality

Poor water quality has been implicated as a cause of fish kills in 1995, 1996, and 1997 (Perkins et al. 2001). The ultimate cause of the UKL water quality problem is excessive nutrients, especially nitrogen and phosphorous, due to natural inputs, external sources, and internal loading (see Water chapter). UKL was historically eutrophic and the bitter, foul water was described in early accounts (Williamson and Abbot 1857). However, sediment cores of the lake bottom show the nutrient budget of UKL has changed dramatically in the past 50–100 years (Eilers et al. 2001). Sediment cores show increases in the sediment accumulation rate, nitrogen and phosphorus concentrations, and a shift toward the nuisance alga responsible for existing poor water quality (Eilers et al 2001).

"Natural input" is synonymous with "background" concentrations that existed in the absence of "recent," post-1900 human activity. Upper Klamath Basin has extensive upwelling of groundwater containing nitrogen and phosphorous (Water chapter). External sources of nutrients are those that originate "upstream" from UKL and enter the lake via surface water run-off or groundwater upwelling. Multiple anthropogenic activities contribute nutrients to UKL, including cattle grazing, agricultural fertilizer, and drainage of wetland (Bortleson and Fretwell 1993; Snyder and Morace 1997; Risley and Laenen 1999). Soil erosion and domestic sewerage practices are lesser. Wetland soils of the Klamath Basin have a high percentage of organic matter, normally maintained in the soil as refractory material (undecomposed remains of plants), and not biologically available. Drainage of wetlands dries the soil, allows oxygenation that promotes aerobic bacteria which decompose refractory material and produce bio-available nutrients, which can enter UKL either via groundwater discharge or during seasonal pumping of drainage water. The production and export of external nutrient loads to UKL is exacerbated by loss of the filtering effects of wetlands and streamside riparian vegetation. These habitats filter and immobilize nutrients by capturing particulate matter suspended in surface run-off and by uptake of nutrients transported in groundwater (Gregory et al. 1991; Kauffman et al. 1997; Naiman and Décamps 1997).

"Internal loading" is the liberation of nutrients from the lakebed into the water column. Nutrients bound to sediment are not biologically available until liberated into the water column. It is estimated that up to 61 percent of the annual phosphorous budget of UKL comes from internal loading (Kann and Walker 1999). Internal loading is particularly troublesome in UKL because it happens in summer when water quality already may be stressful to fish. The high pH, which can cause stress to fish, also initiates internal loading, triggering or maintaining algal blooms and further exacerbating the situation. A primary contributor to the annual budget of internally loaded nutrients is the decayed remains of previous years' algae.

Although the relationships between nutrient load, water quality, and lake elevation are complex and non-linear, it is thought that higher lake levels promote better water quality (Kann 1995; Loftus 2000; Reiser et al. 2001). Specific mechanisms by which lake elevation influence water quality include, but are not limited to, dilution of nutrients and algae, delaying onset of algae blooms, lower water temperatures via a greater resistance to heating, higher dissolved oxygen availability and re-supply rate, and reduced internal loading. Poor water quality results from large algal blooms interacting with climatic conditions such as speed, direction, and duration of wind. Wind speed has been suggested as a significant influence on oxygen levels in UKL during late summer, and therefore, an important factor in fish kills (USFWS 2001). Wind mixes atmospheric oxygen into the water column but also may re-suspend bottom sediments and liberate nutrients (Laenen and Le Tourneau 1996; Wood 1999). Although wind is not manageable, the 2001 BiOp suggested that higher lake elevations could ameliorate the negative consequences of low summer winds. Therefore, an important management goal must be the reduction in magnitude and intensity of algal blooms so that climatic conditions need not be factored into future decision-making.

Access to refugia

In UKL, water quality refugia are most important when low dissolved oxygen and high temperature, pH, and unionized ammonia create stressful conditions for suckers in late summer and early fall. These conditions are typically created when blue-green algae concentrations are highest or when the algae have begun to die-off. Groundwater springs and the mouths of inflowing tributary streams are sites of better water quality (Buettner and Scoppettone 1990) and may serve as refugia from the stressful conditions of the main lake body (Vincent. 1968). Use of water quality refugia by adults appears to be limited by water depth. Radio-tracked daytime depth of adult suckers indicate a preference for depths of 6–9 ft and avoidance of water 0–3 ft deep (Buettner 2000; Reiser et al. 2001). It is unclear whether suckers will choose poor, deep water over good, shallow water since both behaviors have been observed. Bienz and Ziller (1987) report finding between 100 and 200 adult suckers in Pelican Bay on August 27, 1986, a period when the main body of UKL had poor water quality, and Reiser et al. (2001) report limited evidence that suckers utilize Pelican Bay during episodes of poor water quality. However, these authors and others suggest that the observed suckers were “lethargic” and potentially in poor health. Large numbers of dead suckers were collected from Pelican Bay and other “clear water” areas of the lake during the fish kills of the mid-1990s. Conversely, at lake levels below 4,137.0 ft, suckers have been found to relocate away from the northeast shore of UKL, to the west where deeper water is available but quality is more stressful (Reiser et al. 2001).

The 2001 minimum elevation for UKL on July 15 was 4,141.5 ft and on September 15, 4,140.5 ft. These levels were specified, in part, to ensure adequate water depths in areas of groundwater and tributary inflows so that adult suckers could gain the benefits of high quality water without the presumed stress of shallow water. At levels above 4,141.0, 38–40 percent of the lake has a depth of 6–9 ft, the preferred depth of suckers. At 4,140.0 ft, 27 percent of the lake is in the 6–9 ft depth range, and at 4,139.0 about 18 percent of the lake is in this range (Reiser et al. 2001). Because refugia tend to exist around the periphery of the lake, it is likely that the rate of loss of refugia at preferred depths is greater than for the lake-wide values given above.

The Biological Opinions

Although closure of the snag fishery occurred before federal listing, it was a critical management decision that allowed the remaining old fish the opportunity to reproduce and the populations to begin recovery. All subsequent actions have helped promote recruitment or ensure that some proportion of females live long lives, 20–30+ years. The 1992 BiOp recognized that successful annual recruitment was not expected in long-lived species and allowed 4 in 10 years of compromised (lowered) lake elevation. More recently, a series of fish kills from 1995to 1997 added an adult mortality rate similar to or greater than the annual historical snag fishery. This led to increased uncertainty about previous assumptions, and more recent actions have attempted to increase the probability of recruitment and reduce the probability of fish kills.

Prior to the April 2001 BiOp, The Klamath Project had operated under a 1992 BiOp and subsequent amendments (except in 1997 when the Project operated without a BiOp—R. Larson, personal communication).. The 2001 BiOp is notably more “conservative” in protecting the aquatic system, requiring higher water levels to be maintained in UKL. The movement of the Service to a more conservative stance appears to be linked to four factors—a benefit of the doubt instruction, failure to implement requirements and recommendations specified in the 1992 Biological Opinion, a perception of greater imperilment of the sucker species since 1992, and a greater emphasis on water quality issues since 1992.

The most influential factor appears to be that “Congress instructed the Service to provide the ‘benefit of the doubt’ to the species of concern when formulating its biological opinion” (H.R. Conf. Rep. No. 697, supra, at 12; p. 124 of 2001 BiOp, page numbers are those for Section III, part 2). When there is uncertainty, as exists in any complex ecosystem such as Upper Klamath Lake, this instruction suggests that the Service always must select upper confidence bands. The difference between 1992 and 2001 decisions appears to be a more optimistic view in 1992 that managing lake elevations near the post-1921 average, stopping the fishery, salvaging suckers from irrigation ditches, and enhancing spawning sites would lead to recovery. The large fish kills observed during this management regime suggest doubt about this optimistic view.

Failure to implement specific recommendations and requirements delineated in the 1992 BiOp was also identified as a factor in the more conservative approach of the 2001 BiOp. Specific issues included installation of a fish screening device to limit entrainment of suckers to the A-Canal, rehabilitation of Barkley Springs, assessing methods of improving sucker passage over Sprague River Dam in Chiloquin, and identifying ways to reduce the projects demand for water and augment supply.

In the Reasonable and Prudent Alternative section of the 1992 BiOp, USFWS wrote, “Reclamation shall implement a method to reduce entrainment of larval, juvenile, and adult Lost River and shortnose suckers into the A-Canal within five years of issuance of this biological opinion.” On page126 of the 2001 BiOp, USFWS wrote, “Reclamation has not complied with installation of a screen facility requirement on the A-Canal, as directed by an amendment to an RPA in the 1992 BiOp, and has at this time committed to no additional screening at any of its facilities. The fact that adequate screening has not been provided anywhere within the Klamath Project after nearly a century of operation is considered by the Service to be a major factor imperiling and retarding the recovery of the two endangered suckers.” Entrainment of suckers to the A-Canal is significant (Gutermuth, 2000). Salvage operations aim to rescue suckers that are stranded in the A-Canal at the end of irrigation season, but the efficiency of salvage is unclear because the percentage of fish entrained and returned in a viable condition to UKL is unknown and salvage does not rescue larval or smaller juvenile suckers. It is unclear how failure to screen the A-Canal influenced the Service’s decision process for 2001. Because low water elevations allowed for in the 1992 BiOp are now considered to jeopardize suckers, it seems reasonable to conclude that water elevation requirements would not have been more “relaxed” had the A-Canal been screened in compliance with the 1992 BiOp.

Three additional recommendations developed in the 1992 BiOp but not resolved by 2001 are the restoration of Barkley Springs, improving fish passage around the Sprague River Dam, and reducing the demand for water by the irrigation community. Point 8 of "possible mitigation measures" of the 1992 BiOp states, "Historically Barkley Springs was the site of prolific spawning activity. Thirty years ago Hagelstein Park was developed by Klamath County in the immediate vicinity of the springs. Construction of the park included diking, ponding, and the rerouting of water. This caused spawning to essentially cease, although it has been reported that as late as 1973 great numbers of suckers attempted to reach this traditional spawning ground. This work would be completed in time for the sucker spawning runs in March of 1993." In 1993, Reclamation added spawning substrate at two locations at the spring and in 1995 installed a water control device to attempt to ensure the spawning areas were kept at adequate depth throughout the spawning season. Despite these efforts, no sucker spawning has been observed at Barkley Springs in the past decade (M. Buettner, Bureau of Reclamation, personal communication).

Point 9 of the 1992 BiOp states, "Assess Methods to Improve Passage in the Sprague River. If a feasible plan is determined before March 1993, Reclamation will attempt to implement it before spawning in 1993." Between 1992 and 2001, no changes were made to the Sprague River Dam. The Sprague Basin above the dam has been extensively modified from its pre-dam condition, including loss of riparian zones and establishment of exotic fish species. It is unclear whether suckers hatched in the Sprague River would survive in sufficient numbers due to water quality and exotic fishes. It is also unclear whether there would be significant downstream impacts from the release of sediments accumulating behind the dam, although a Reclamation study done in 1997 documented little sediment deposition behind the dam (Mark Buettner, Bureau of Reclamation, personal communication). Both of these issues appear to have contributed uncertainty about the wisdom of removing or modifying Sprague River Dam.

It is not clear whether implementation of the actions called for in the 1992 BiOp would have changed the decision in the 2001 BiOp. Presumably, if screening had been done and suckers re-established at Barkley Springs and the Sprague River, and these actions could be linked to increased recruitment of juveniles, Service might have concluded that a lower lake elevation was reasonable and prudent. However, the third and fourth caveats, below, suggest in the short term at least, that this is not true.

The third factor influencing Service's shift to a more conservative approach was their position that UKL suckers are more imperiled now than they were in 1992. Page 156 of the 2001 BiOp states, "However, the RPAs have not been fully implemented and evidence now indicates that the two endangered sucker species are more imperiled than when previous opinions were issued." Increased imperilment is not well documented because it has been difficult to get rigorous estimates of the annual adult population size. Instead, the Service noted declines in spawning run indices (Fig. 6) and estimated losses from fish kills in 1995, 1996, and 1997. However, the responses of the populations from 1988 to 1995 are not clear. Essentially, the populations appear to have been increasing from 1988–1995, but those gains were lost in the 1995–1997 fish kills. Because of uncertainty in the adult abundance information it is possible that the authors of both decisions presumed population estimates of about the same order of magnitude.

Even if the Service agreed that population abundances were similar in 1992 and 2001, there are differences in reproductive potential. The older fish present in 1992 would have had much greater reproductive potential than the younger fish in 2001. In addition, the 2001 BiOp uses new information to show that two aspects of the 1992 opinion (Table I-2) required revision. The first was that the 4-in-10-year compromised (lower) elevation of 4,137 ft would jeopardize suckers based on lake elevation—water quality interactions and sucker recruitment and survival. The empirical data from the 2 lowest years (1992 and 1994) show no recruitment (Figs. 1 & 2) and no fish kills, but the latter may have been avoided because of climactic conditions (2001 BiOp). The higher lake elevations required in the 2001 BiOp do not relate solely to water quality and also include access to preferred habitats, and possible delayed effects. Left unanswered is whether compromised elevations of any elevation or frequency create jeopardy. The second is that the uncompromised minimum elevation of 4,139 ft would jeopardize suckers. The BiOp does not show that this elevation is a threat, but given certain climate outcomes, it says it might be a threat. On page 106 of the 2001 BiOp, "The Service acknowledges that meeting prescribed lake elevations does not ensure year-class success or prevent sucker die-offs. Other factors including weather, *AFA* bloom dynamics, disease outbreaks, and poor water quality can all lead to year-class failure and sucker die-offs independent of lake level. However, both Reclamation and the Service recognize that high lake elevations can enhance the probability of year-class survival and reduce the frequency and magnitude of major sucker die-offs, and is the only short-term way to offset some of the threat to sucker populations in UKL." In other words, "Since winds cannot be managed, summer and early fall lake levels in UKL need to be managed near the higher pre-project levels to reduce risk of catastrophic fish kills" (p. 86).

The empirical data suggest uncertainty regarding the size of the benefit of higher lake elevations. Even in "expected" wind-speed ranges with July–August lake elevations greater than 4,141 ft, the data show that a fish kill happened in 2 of 6 years (1995 and 1997). As expected in the worse case "weak wind scenario," a July–August elevation of 4,140.8 ft also was associated with a fish kill (1996). The 2001 BiOp recognizes other factors, primarily AFA bloom dynamics and disease, as confounding this relationship, but as cited above (p. 195), considers higher lake levels as a means to reduce the negative consequences of these unmanageable factors. Because each year provides a different set of circumstances, it is important that long-term data sets be maintained and that modeling and empirical analyses continue.

In summary, the 2001 BiOp makes a case for revising the conditions of the 1992 BiOp. The 2001 BiOp suggests that lowered lake levels are no longer reasonable because of concerns for water quality, population size, age structure, and recruitment. Essentially, the experience since the 1992 BiOp demonstrated uncertainty about the previous choice of a minimum lake elevation. The population size and age structure necessary for lower or compromised lake levels to again be considered reasonable or prudent is not described. Further support for the more restrictive water management program is the congressional instruction to provide "benefit of the doubt," supplemented by a belief in greater imperilment of the species, failure to implement prior requirements, and an increased concern for water quality. The 2001 BiOp makes a case that the 4-in-10-year compromised elevation of 4,137 ft might create jeopardy, but it does not address whether compromised elevations or their frequency can be considered reasonable and prudent in the future. The BiOp also presents an argument for raising the uncompromised elevation 1 foot to 4,140 ft. The argument is primarily based on a potential indirect benefit to ensure against low wind speeds, but the amount of insurance provided by 1 foot of lake elevation is not described.

The decision process

Although there was no requirement for peer review, the 2001 BiOp was sent to peer reviewers as a rough draft (dated February 5, 2001) and as a final document (dated April 5, 2001). The rough draft was reviewed by researchers actively working in the Basin and the final draft reviewed by additional groups (University of California Davis, the Governor's Independent Multidisciplinary Science Team, and the National Research Council). Widespread misunderstanding of the peer review process was evident in the local community. Ideally, peer review is constructively critical, but our negative critical review of the rough draft received wide circulation while more positive critical reviews of the final draft by us, and others, did not. To some extent it appeared that peer criticisms of the BiOp were equated with the idea that there were no problems for suckers—an incorrect interpretation. The intellectual process of science is iterative, as it applies to both single documents and to long-term management. In the case of Upper Klamath Lake management, the 2001 BiOp was a new iteration of the 1992 BiOp. For example, changes from the 1992 BiOp might have been due to changes in the abundance, and therefore the perceived threat to suckers, or to changes in the nature of the threats. The 2001 BiOp made both claims and the function of peer review was to critically challenge them. Some claims, such as changes in adult abundance since 1992, were not well documented. Challenges to those claims did not mean that the populations were healthy. The primary evidence was declines since 1995, but there were apparently increases in the late 1980s to early 1990s, such that abundances in 2001 may not have been substantially different than 1992 even though age structure probably was different. Other claims, such as fish kills, were well documented and substantially altered the nature of threats.

The public is not served when it misunderstands or is misled by the critical nature of peer review. It is a process that seeks to refine and improve data collection, analysis, and interpretation. The use of critical peer reviews to claim that the decision or the process behind the 2001 BiOp were based on "junk science" is wrong, confounds a difficult situation, and deflects energies away from solving real problems.

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