Status of Kokanee Populations in the Kootenai River in Idaho and Montana and South Arm Kootenay Lake, British Columbia

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INTRODUCTION

The Kootenay Lake watershed has received considerable attention from the scientific community for well over fifty years due to a series of human influences that have resulted in dramatic changes in lake productivity. These changes have profoundly affected several fish species, most notably kokanee (*Oncorhynchus nerka*). Introduction of the non-native crustacean *Mysis relicta*, pollution abatement, habitat changes, and completion and operation of two large hydropower dams on major Kootenay Lake tributaries, Libby Dam, completed in 1972 near Libby Montana on the Kootenai River, and Duncan Dam on the lower Duncan River BC, completed in 1967, and other factors have contributed to collapsing kokanee populations and underlying nutrient deficiency in the lake by the 1980s (Ashley et al. 1997; Ashley et al. 1999; Schindler et al 2007a). A team of aquatic scientists and fishery mangers convened a series of meetings and workshops to address this problem during the late 1980s and early 1990s. These efforts ultimately resulted in an experimental nutrient addition program in Kootenay Lake's North Arm that began in 1992 (Ashley et al. 1997; Ashley 1999; Schindler et al 2007a). Since then the North Arm fertilization program has been successful in restoring nutrient availability and in conjunction with spawning channels, kokanee production and fishery opportunities for kokanee and other native larger resident salmonids (Ashley et al. 1997; Ashley 1999; Schindler et al 2007a).

Similarly, a native kokanee stock that historically reared in Kootenay Lake's South Arm and spawned upstream in Kootenai River tributaries in Idaho, with reported harvest rates as high as 25 fish per hour in the 1980s (Partridge 1983), was considered functionally extinct by the early 1990s, coincident with the aforementioned collapse of kokanee stocks in Kootenay Lake downstream in British Columbia (Ashley and Thompson 1993; Ashley et al. 1997; KTOI and MFWP 2004). However, after decades of unsustainably low natural production, recent observations of kokanee spawning in lower Kootenai River tributaries in Idaho are being viewed with cautious optimism.

Modeled after the successful North Arm Kootenay Lake nutrient addition program, an integrated international effort to re-establish spawning populations throughout the Kootenai Basin in Idaho and British Columbia was subsequently undertaken. Tributary habitat restoration efforts began in several Kootenai River tributaries in Idaho during the early 2000s, and kokanee egg plants in Idaho tributaries began in 1997 (Ashley and Thompson 1993; KTOI and MFWP 2004; Kruse 2007). One hundred thousand to 500,000 eyed kokanee eggs (Meadow Creek stock) were planted annually in three tributaries during the late 1990s compared to 150,0000 to 3 million eggs per stream in each of six streams during most years since 2003. Experimental fertilization was initiated in Kootenay Lake's South Arm in 2004 and in the Kootenai River at the Idaho-Montana border in 2005. All fertilization, egg planting, and habitat restoration programs are ongoing.

This report: (1) summarizes and characterizes past and current kokanee status, (2) documents changes in spawning abundance with and without reintroductions and enhancement efforts, and (3) provides recommendations to address current and future research and management needs for kokanee in the Kootenai River Subbasin.

Kootenai kokanee overview

The Kootenai[1] River is a tributary of the Columbia River located between 48° and 51° north latitude and 115° and 118° west longitude, and it includes parts of southeastern British Columbia, northern Idaho, and northwestern Montana (Figure 1). The Basin measures approximately 381 km by 245 km with an area of 41,421 km^2. Roughly two thirds of the river's 776-km-long channel and nearly 70% of its watershed area are located within the province of British Columbia. The Montana portion of the Basin comprises about 23% of the watershed, with the remaining 7% percent in Idaho (Knudson 1994).

Kokanee are native to the Kootenai Basin downstream from Kootenai Falls in Montana (KTOI and MFWP 2004). A non-native kokanee population was founded in Lake Koocanusa (the impoundment created by Libby Dam) by fish from the Kootenay Trout Hatchery upstream in BC near the town of Wardner (Figure 1). This population is an admixture of non-native stocks, including Meadow Creek (a dominant native North Arm Kootenay Lake stock) and a mix of western BC stocks (Appendix Table 1; Anders et al. 2007). Kokanee were also stocked into Moyie Lake in BC (Appendix Table 2) and Bull Lake in Montana (Appendix Table 3), both of which flow into tributaries to the Kootenai River (Figure 1). Historically, native kokanee existed as three native stocks in Kootenay Lake and as seasonal residents in Idaho waters of the Kootenai River and its tributaries. A more detailed account of these kokanee stocks or populations is presented in the "Focal and Target Species" section of the Kootenai River Subbasin Plan (KTOI and MFWP 2004) and in a recent microsatellite analysis genetic report (Anders et al. 2007).

British Columbia - The majority of native kokanee in the Kootenai River Subbasin rear in Kootenay Lake in British Columbia (Figure 1). Vernon (1957) described three morphologically distinct stocks of kokanee in Kootenay Lake: (1) a North Arm (that portion of the lake north of the West Arm) stock that spawned at age 4 (mean size 21.5 cm); (2) a South Arm (that portion of the lake south of the West Arm) stock that spawned at age 3 (mean length 18.5 cm); and (3) a West Arm stock that spawned at age 3 (mean length 24.5 cm). The South Arm stock spawned first (early August to mid-September) followed by West Arm (mid-August to mid-September) and North Arm fish (late August to mid-October).

The North Arm Kootenay Lake kokanee population has been monitored for over 40 years (Sebastian et al. 2007). Escapement into North Arm spawning tributaries has been estimated to be as high as 4.1 million (Bull 1964) and as low as 200,000 fish (Andrusak et al. 2007). Population abundance of North Arm kokanee increased following nutrient enhancement that began in the North Arm in 1992 (Sebastian et al. 2007). Smaller numbers of kokanee currently spawn in several West Arm Kootenay Lake tributaries. Escapements to local streams in the lower West Arm have been periodically monitored with only a few (100 to 1,000) spawners observed annually (Andrusak et al. 2007).

The ecology of Kootenay Lake has changed significantly since the middle of the last century. In an attempt to enhance trout populations, mysids (freshwater shrimp) were introduced into the lake in 1949 (Northcote 1991). The mysid population was initially thought to have a positive effect on West Arm kokanee because the shallow bathymetry of the arm allowed fish to access

[1] The Kootenai is spelled Kootenay in Canada.

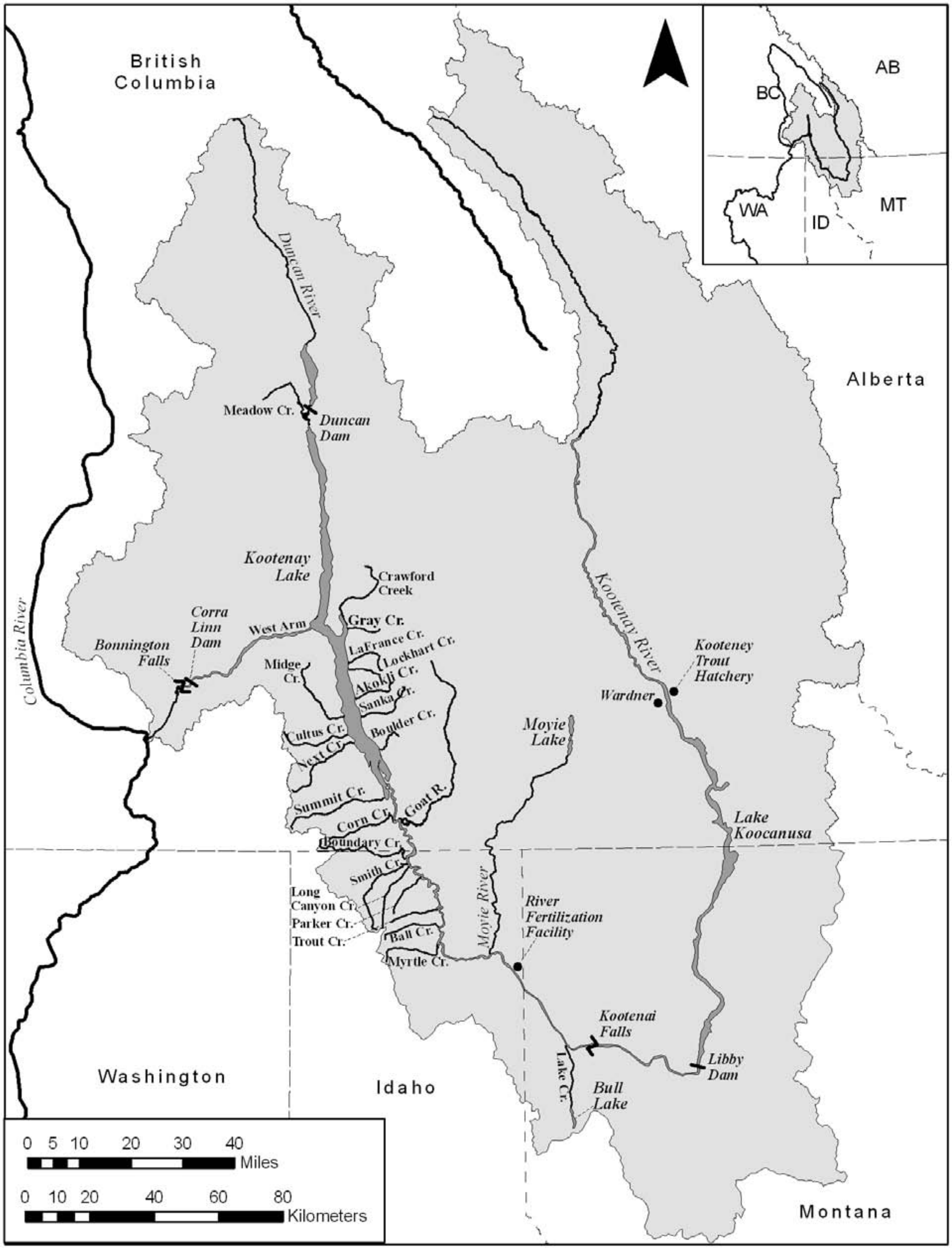

Figure 1. Map of the Kootenai River Basin in British Columbia, Montana, and Idaho.

and feed on them. However in the deeper main-lake, mysids remained in deep water and were inaccessible to visual feeding kokanee. Further, the mysid population competed directly with juvenile kokanee for zooplankton. Thus, the cumulative effect of the introduction of mysids into Kootenay Lake on the kokanee population has been described as unremarkable to undesirable (Martin and Northcote 1991; Northcote 1991). The negative impacts of the introduction may have been initially masked by cultural eutrophication of the lake. Eutrophication resulted from a phosphate fertilizer plant discharging significant amounts of nutrients into the lake beginning around 1953 until the plant closed in 1973 (Northcote 1973). Following the plant closure and completion of the Libby Dam in 1972, the lake experienced a period of denutrification (Ashley et al. 1997). The reservoir created by Libby Dam (Lake Koocanusa) acts as a nutrient sink, trapping nutrients upstream (Larkin 1998). The combined closure of the fertilizer plant and reduction of nutrient inputs resulted in a significant loss of productivity in Kootenay Lake in the early 1980s.

Idaho - The native kokanee stock that historically spawned in tributaries of the lower Kootenai River in Idaho after rearing to maturity in the South Arm of Kootenay Lake was reported as functionally extinct by the early 1990s (Ashley and Thompson 1993). Spawning escapements from this stock numbered into the thousands of fish as recently as the early 1980s (Partridge 1983; Anders 1993; Ashley and Thompson 1993). Between 1996 and 1999, visual observations and annual redd counts in five Idaho tributaries found no spawners returning to Trout, Smith, and Parker Creeks, while Long Canyon and Boundary Creeks had very few kokanee returns (KTOI and MFWP 2004). Andrusak et al. (2004) summarized available historic escapement data for this population and concluded that total annual escapements even prior to hydro-development impacts did not likely exceed 200,000 fish.

***Montana* –** Kokanee are native to the Kootenai River below Kootenai Falls, about 34 river km upstream of the Idaho/Montana (Figure 1). However, the introduction of non-native kokanee to upstream portions of the Basin vastly increased their range and likely affected kokanee populations downstream in Idaho and Kootenay Lake.

Montana Fish Wildlife and Parks (MFWP) stocked non-native kokanee into Bull Lake (Figure 1) which drains into Lake Creek (Kootenai River tributary) since 1953. These non-native kokanee originated from out-of-basin stocks, primarily from western Montana but also Wyoming and Colorado (Appendix Table 3). It is unknown whether kokanee migrate out of Lake Creek in great numbers. However, adult kokanee return during the fall to accessible sections in lower Lake Creek. Upstream migration is currently blocked by a 12 m natural falls and 13 m high hydroelectric dam located about 1.5 km upstream of the Kootenai River (Northern Lights, Inc. 2008). The origin of these fish is unknown; they may have entrained as juveniles through Lake Creek or Libby Dam, or strayed from other areas. Nevertheless, MFWP has opened a snag fishery on Lake Creek to maximize harvest of these fish under the assumption that they are non-native.

Non-native kokanee were inadvertently introduced into Lake Koocanusa soon after the completion of Libby Dam. Nearly 1.5 million reported moribund fish from British Columbia's Kootenay Hatchery near Wardner were discharged into Norbury Creek (an upper Kootenay River tributary in BC) between 1969 and 1978 (Appendix Table 1). These hatchery stocks represented within basin (Meadow Creek) and outside basin stocks (Okanagan and Chilliwack). Some of these non-native kokanee survived and rapidly expanded into the newly created reservoir. No kokanee were sampled in Lake Koocanusa creel surveys in 1979 (Oliver 1980) but by 1985 the harvest of kokanee in this fishery exceeded 575,000 fish (Dalbey et al. 1998). Two years later, the abundance of kokanee in the lake peaked at 5.7 million fish (Skaar et al. 1996). Escapement surveys conducted between 1996 and 2003 in upper Kootenay River tributaries counted 116,113 to 452,740 spawners annually (Westover 2003).

Recent quantitative population abundance, escapement, and fishery catch data for kokanee in Montana portions of the Kootenai River Basin are lacking (KTOI and MFWP 2004, Jim Dunnigan, MFWP, personal communication). Hydroacoustic estimates of kokanee abundance in Lake Koocanusa were available from 1984 to 1991 (Figure 2). Hydroacoustic data were also collected from 1992-1994 but never analyzed (Mike Hensler, MFWP, personal communication). The most consistent information on Lake Koocanusa fish population trends comes from MFWP annual spring (sinking nets) and fall (floating nets) gill net sampling since 1975 (Dalbey et al. 1998, Dunnigan et al. 2008). Kokanee were first caught in fall sampling in 1980, and catch rates peaked in 1988 coincident with the highest hydroacoustic estimate (Figure 2). Subsequently the fall gill net kokanee catches trended downward until about 1995, and have since trended upward (Figure 2; Dunnigan et al. 2008). Although gill net catches vary widely from year to year, fall catches generally trended with available hydroacoustic abundance estimates (Figure 2). Creel surveys have not been conducted since 1990. A bi-annual statewide mail survey provides estimates of angler effort but not catch.

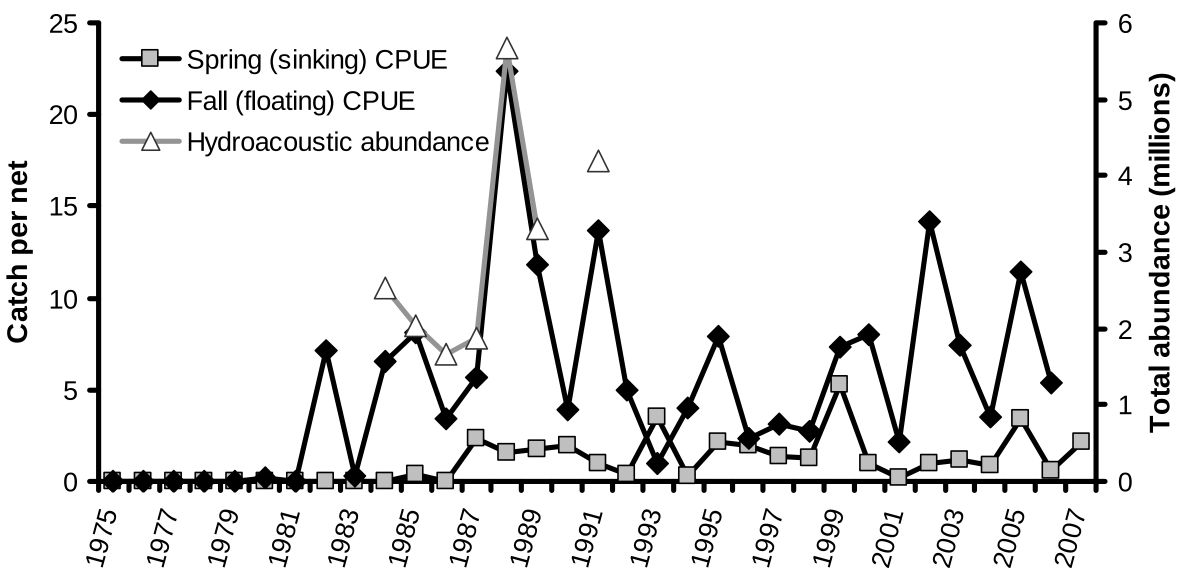

Figure 2. Comparison of spring and fall kokanee abundance indices (catch of kokanee per net) used in Lake Koocanusa, 1975-2007 with hydroacoustic estimates of total abundance, 1984-1991.

Several authors have noted evidence of density-dependent growth of kokanee in Lake Koocanusa. The mean length of kokanee caught in MFWP fall gill nets has varied annually but generally trended downward since 1998 (Figure 3). Skaar et al. (1996) attributed a reduction in the mean spawner length from 410mm in 1986 to 257mm in 1990 to density-dependent growth. Similarly, Dalbey et al. (1998) cited density-dependent growth as a possible cause for the

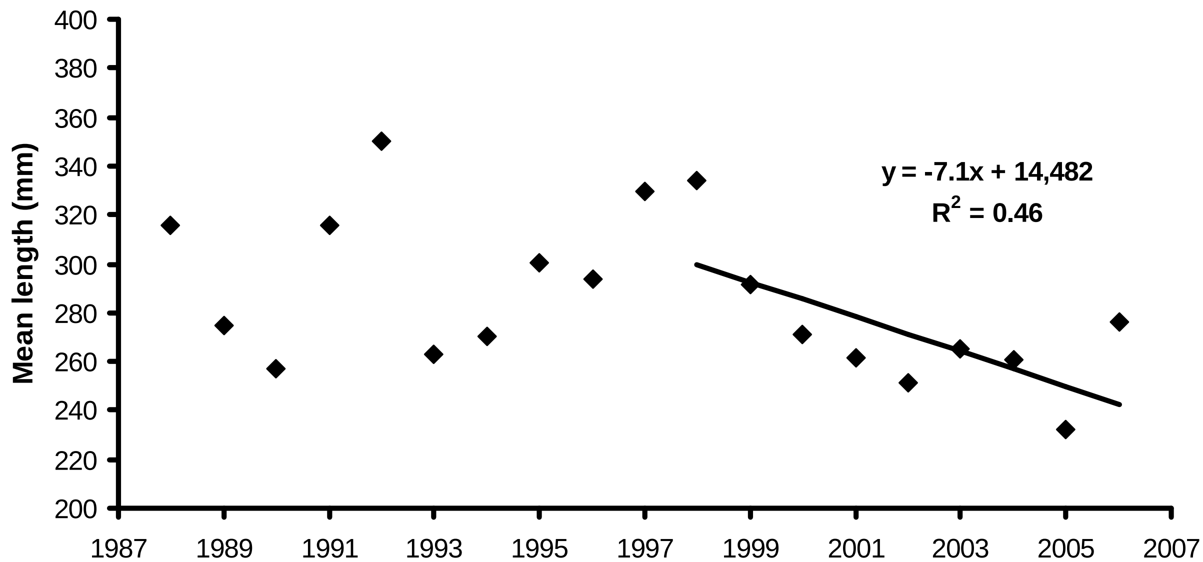

Figure 3. Mean length of kokanee caught in Lake Koocanusa fall floating gill nets, 1988-2006. The mean size of kokanee trended downward between 1998 and 2006. Data taken from Dunnigan et al. (2008).

reduction in the mean length of kokanee harvested in the lake between 1985 and 1990. They suggested that angler preference for larger fish was the primary reason for a sharp decline in angler effort and kokanee harvest in the lake between 1985 and 1990. Hoffman et al. (2002) found that fall kokanee length was negatively correlated to kokanee escapements for the years 1996-2001. Despite the lack of quantitative abundance and fishery harvest data, MFWP increased the Lake Koocanusa kokanee limit in 2008 to 50 per day and 100 in possession in an effort to reduce population density and improve growth (Jim Dunnigan, MFWP, personal communication).

Movement of non-native kokanee from Lake Koocanusa downstream via entrainment through Libby Dam has not been well documented, but has been significant in the past. Skaar et al. (1996) estimated between 1.15 and 4.47 million fish were entrained through the Libby Dam in 1992. The vast majority (97.5%) of the entrained fish was kokanee salmon, primarily age 0+ fish. The controlled entrainment of kokanee through Libby Dam has been suggested as a means to reduce population density and increase the size of kokanee in the lake (Skaar et al. 1996). Following entrainment, kokanee can remain in Montana waters upstream from Kootenai Falls to the dam, they can pass below the falls and remain in the canyon reach, or they can pass below the falls and migrate further downstream to rear and mature in Kootenay Lake. Entrained kokanee that survive to maturity upstream from Kootenai Falls converge as spawners in the Libby Dam tailrace which blocks further upstream migration (Libby Dam has no upstream fish passage facilities). Entrained kokanee that rear downstream of Kootenai Falls (presumably in Kootenay Lake) converge below the falls during spawning migrations because the falls act as an upstream migration barrier (Brian Marotz, MFWP, personal communication). MFWP opened up a snag fishery in the Kootenai River immediately below Kootenai Falls to harvest mature kokanee that could not migrate up Kootenai Falls. Since the early 1990s, the frequency and magnitude of Libby Dam's power peaking operations were greatly reduced to more closely emulate pre-dam conditions in order to address downstream ecosystem and fisheries needs. This change in operations is thought to have significantly reduced entrainment of kokanee through Libby Dam and participation and harvest in the snag fisheries has dropped noticeably (Jim Dunnigan, MFWP, Libby Field Station, personal communication, November 2008). The roles of spring "sturgeon flows" (Duke et al. 1999; USFWS 1999) and the newly implemented (2008) fall power peaking operations on kokanee entrainment through Libby dam are unknown, but may increase entrainment. Although unquantified, spring or early summer spill tests or emergency spill events at Libby Dam, such as occurred during 2002 (Dunnigan 2002) and 2006 (Marotz et al. 2007) likely increase kokanee entrainment. MFWP is currently developing efforts to assess effects of such operation in reservoir and river fisheries and fish populations. These efforts may include hydroacoustic surveys to estimate Lake Koocanusa kokanee abundance (Mike Hensler, MFWP, personal communication).

Entrainment of kokanee from Libby Dam has been suggested as a possible cause for the decline of native South Arm stocks (Schindler et al. 2007b). Non-native kokanee that emigrated downstream of Kootenai Falls most likely reared in the South Arm of Kootenay Lake. These fish would have directly competed with the few native kokanee produced in South Arm tributaries.

Population genetics

Anders et al. (2007) analyzed microsatellite samples collected in the Kootenai Basin to define and assess kokanee populations and their potential stock structure in Idaho, Montana, and British Columbia. A total of 277 samples were analyzed: 60 from Lake Koocanusa tributaries in British Columbia, 30 from Kootenai River tributaries in Idaho, and 187 from Kootenay Lake or Kootenay River tributaries in British Columbia. Samples were primarily collected from kokanee spawning tributaries. Their analyses identified two distinct clusters (populations) in the Kootenai River Basin; Lake Koocanusa individuals assigned primarily to Cluster 1 (87%), and Kootenay Lake individuals assigned primarily to Cluster 2 (56%). Nearly half (47%) of the Kootenai River individuals assigned to Cluster 1, whereas about 23% were classified as "in between" the two clusters (inferred membership assignment < 60% to either cluster). In addition, the North Arm (Meadow Creek) samples were genetically distinct from those collected from West and South Arm tributaries of Kootenay Lake, consistent with past stock structure assignments based on morphometric and spatial and temporal isolation among these stocks (Vernon 1957).

Regional genetic comparisons indicated that the Kootenai River in Idaho may be a transitional area between Lake Koocanusa and Kootenay Lake (Anders et al. 2007). In particular, Long Canyon Creek appeared to be genetically distinct from the Lake Koocanusa population, and from two of the Kootenay Lake populations. However, except for Long Canyon Creek, the Idaho region lacked adequate sample sizes required for statistical comparisons among tributaries within the region or to individual tributaries in other regions. Thus, results for kokanee sampled from Idaho tributaries were considered preliminary and could change with additional genetic sampling.

Although one objective of the genetic study was to determine the contribution of kokanee entrained at Libby Dam to downstream rearing and/or spawning populations (Anders et al. 2007), this issued remained unresolved due to the widespread introduction of Meadow Creek stock throughout the Basin. Significant numbers of Meadow Creek kokanee stock were introduced into Lake Koocanusa during the latter release years (Appendix Table 1). Therefore the Koocanusa/BC (Cluster 1) kokanee could not be distinguished from other Meadow Creek fish that were planted as eyed eggs into Idaho tributaries using genetic methods.

RESTORATION AND REINTRODUCTION EFFORTS

Numerous efforts have been initiated to enhance or restore kokanee abundance and habitat in the Kootenai River Basin since 1990. These include lake and river fertilization, tributary habitat restoration, and re-introduction efforts. Each of these activities is described below.

Kootenay Lake nutrient additions

The main lake populations of kokanee, the keystone species within Kootenay Lake, declined in the early 1990s to the lowest levels recorded in over four decades. Reasons for the decline were attributed primarily to the reduction of nutrients to the lake combined with direct competition for food resources by introduced mysids (Northcote 1991; Ashley et al. 1997; Ashley et al. 1999). Adaptive management efforts were implemented to counter these forces and restore kokanee numbers to historic pre-dam levels. Nutrient additions were initiated in 1992 in the North Arm to reverse declining lake productivity (Ashley et al. 1997; Ashley et al. 1999; Schindler et al. 2007a). The Fish and Wildlife Compensation Program – Columbia Basin, funds the North Arm Kootenay Lake project. The North Arm kokanee population appears to have responded positively to the nutrient additions and by the mid-1990s escapement levels approximated those of the 1970s (Schindler et al. 2007b). A nested experimental reduction in fertilizer loading from 1997-2000 resulted in a steep decline in the kokanee abundance and the higher nutrient loading rate was resumed in 2001 to satisfy restoration goals (Schindler et al. 2007b).

An experimental fertilization program on the West Arm of Kootenay Lake was conducted in 1986 and 1987 (Perrin 1988). However, this effort was discontinued after it was determined that growth of fry in the West Arm was not food limited (Perrin 1988).

In contrast to the response of the North Arm kokanee to nutrient additions, the South Arm tributaries remained virtually devoid of kokanee. As part of an effort to reintroduce kokanee to South Arm and Lower Kootenai River tributaries, fertilization efforts were undertaken on the South Arm of Kootenay Lake beginning in 2004 (Table 1). The fertilization project on the South Arm was funded by the Bonneville Power Administration through the Kootenai Tribe of Idaho. These efforts are coordinated through the Subbasin Plan and are designed to restore impacted fish species with particular emphasis on kokanee in Kootenay Lake (BC) and the Kootenai River (Idaho) (Anders et al. 2004). Although kokanee returns to some Idaho tributaries have increased substantially during recent years, a time series of annual returns is needed to conclude whether nutrient additions and/or other efforts have been successful in re-establishing sustainable kokanee populations to South Arm and Idaho tributaries.

Kootenai River nutrient additions

The largest experimental river fertilization project to date began in the Kootenai River just downstream from the Idaho-Montana border (Figure 1) in 2005. This project was initiated in response to nutrient poor (ultraoligotrophic) conditions in the Kootenai River due to the loss of the historic floodplains and the trapping of nutrients in Lake Koocanusa (Daley et al. 1981; Woods 1982; Snyder and Minshall 1994-1996, 2005; Snyder 2001).

A custom-built solar-powered nutrient addition system was used to provide a low dose of dissolved nutrients (10 to 40 L/hour) that was varied according to river discharge (Table 1; Holderman et al. *In prep.*). Dosing of ammonium polyphosphate solution occurred annually for the summer growth period from June 1st to September 30th. Dosing was adjusted by the site operator according to daily flow levels to maintain the appropriate dilution levels (1.5 µg/L in 2005, 3 µg/L thereafter) as required by the U.S. Environmental Protection Agency permit. Volumes of about 50 to 70 thousand liters of 10-34-0 fertilizer were used annually, depending on run-off amounts. Total annual Kootenai River nutrient inputs are found in Table 1.

Table 1. South Arm Kootenay Lake[a] and Kootenai River [b] nutrient additions, 2004-2008.

	Metric tons of nutrient	
	South Arm	Kootenai River
Year	Nitrogen	Phosphorus
2004	124	0
2005	234	4.5
2006	257	7.3
2007	245	13.9
2008	265	10.7

[a] South Arm Kootenay Lake data through 2005 taken from Schindler et al. 2007b. 2006-2008 data provided by Eva Schindler (Ministry of Environment, Nelson, BC, personal communication).

[b] Kootenai River data provided by Hassen Yassien (Ward and Associates, Vancouver, BC, personal communication). Ongoing monitoring has indicated that nitrogen is not limiting river production to date. However, small amounts of nitrogen were present in the fertilizer mixture.

Ongoing monitoring is being conducted in the Kootenai River to assess effects of the river fertilization project on local fish and invertebrate populations (Charlie Holderman, Kootenai Tribe of Idaho, personal communication). Monitoring is typically conducted in September and kokanee are occasionally caught and measured for length (Appendix Table 4).

Although the river fertilization program should primarily benefit resident fish of the Kootenai River, the effort may provide a benefit for fish rearing in the South Arm of Kootenay Lake since the Kootenai River can contribute up to 80% of the inflow to Kootenay Lake (Northcote 1972). Kokanee originating from Idaho tributaries spend most of their life rearing in Kootenay Lake and are more likely to benefit from nutrient additions to the South Arm.

Lower Kootenai tributary habitat enhancement

The Lower Kootenai River and tributaries that historically supported kokanee production have been impacted from land use practices and habitat loss. Levees and channelization have isolated and drained much of the historical floodplain since the early 1920s (KTOI and MFWP 2004). Fish habitat in lower Kootenai River and tributaries has been altered by road-building, cattle grazing, agricultural and logging practices, and development. These activities have degraded water quality, elevated water temperatures, increased sedimentation, removed riparian vegetation, and reduced habitat diversity (Kruse 2007). Direct impacts to trophic processes and overall productivity of the lower Kootenay River and tributaries are difficult to quantify but are likely significant.

The Kootenai Tribe of Idaho has been working with local landowners since 2001 to restore fish habitat to lower Kootenai River tributaries with base funding provided by the Bonneville Environmental Foundation (BEF) and Bonneville Power Administration, along with targeted funding from grants as needed (KTOI and Kruse 2002). The lower Kootenai River in Idaho was one of the first sites adopted under the BEF Model Watershed program (Reeve et al. 2006, Reeve and Towey 2007). Under this program, BEF and Kootenai Tribe of Idaho signed a memorandum of understanding (MOU) that provided funding for monitoring and evaluation, professional scientific support, and the services of an independent peer-review team for a 10-year period (2003-2013). The MOU formalized the intent of BEF and Kootenai Tribe of Idaho to coordinate, develop, and implement a 10-year Model Watershed restoration and monitoring program and partnership in the lower Kootenai River.

The long-term goal of the Kootenai River tributary restoration program is to restore, preserve and protect a properly functioning ecosystem that protects the abundance, productivity, and diversity of biological communities and habitats across the Kootenai River watershed (Kruse 2007). The short-term project goal is to improve water quality, habitat, and ecosystem function from headwaters to confluence in five lower Kootenai River tributary streams (Kruse 2007). Habitat restoration activities have been initiated on three streams to date: Trout, Parker and Long Canyon Creeks (Figure 1). These streams were prioritized for habitat enhancement activities based on potential water and riparian resource problems, as well as tribal cultural significance and landowner interest. Because the upper watersheds of the streams were considered to be in high functioning condition, restoration efforts have been focused on rehabilitating the lower transition and historical floodplain sections.

Habitat restoration activities have primarily focused on improving grazing management (i.e. rest, rotation, temporary fencing, off stream watering options) and re-establishing native plant species within the riparian zone. Instream improvements, such as placement of woody debris and bank stabilization have also been implemented where appropriate. In addition to the three streams mentioned, biological and physical habitat monitoring activities have also been conducted on Fisher and Myrtle Creeks under the program (Kruse 2005; GeoEngineers 2005).

Kokanee reintroduction

Kokanee eyed eggs have been planted in various South Arm and Kootenai River tributaries within Idaho and British Columbia in an effort to stimulate natural production. The Kootenai Tribe of Idaho began planting eyed eggs (Meadow Creek stock, North Arm Kootenay Lake) in Idaho tributaries in 1997 (Table 2). The number of eggs planted each year depended on the availability of Meadow Creek brood stock. For example, no eggs were available for out-planting during 2000 to 2002. The number of eyed eggs planted increased significantly beginning in 2003 (Table 2). Progeny from the 2003 plant were expected to return to spawn in 2007. Although kokanee eggs have been planted in South Arm (BC) streams as early as 1929 (Andrusak et al. 2004), recent efforts were not initiated until 2005 (Table 3). Adults resulting from these recent egg plants are not expected to return to BC streams until 2009.

The Freshwater Fisheries Society of BC incubated Meadow Creek kokanee eggs to the eyed stage at the Kootenay Trout Hatchery and transported them to stream sites for planting. Streams

Table 2. Number of Meadow Creek stock eyed kokanee eggs planted in Idaho tributaries, 1997-2008. Data provided by the Kootenai Tribe of Idaho.

	Idaho tributaries								
Year	Boundary	Long Canyon	Parker	Trout (S. fork)	Trout (N. fork)	Ball	Myrtle	Fisher	Combined
1997		100,000							100,000
1998		100,000	100,000[a]	100,000					300,000
1999		200,000	150,000	150,000					500,000
2000-02				No egg-plants					0
2003		417,000	417,000	417,000	50,000		200,000		1,501,000
2004		500,000	500,000	587,500	325,000		587,500	500,000	3,000,000
2005		420,000	420,000	420,000	200,000		420,000	420,000	2,300,000
2006		100,000			25,000			25,000	150,000
2007		625,000	300,000	425,000	93,000		150,000	150,000	1,743,000
2008	1,000,000	500,000	50,000	325,000	200,000	325,000		100,000	2,500,000

[a] In addition, 15,000 kokanee fry were released into Parker Creek in the spring of 1998.

Table 3. Number of kokanee planted in British Columbia tributaries, 1929-2008. All plantings were eyed eggs from Meadow Creek stock unless otherwise specified. Data through 1988 taken from Andrusak et al. (2004), and 2005-2008 provided by Eva Schindler (Ministry of Environment, Nelson, BC, personal communication).

	British Columbia tributaries								
Year	Akokli	Boulder	Crawford	Cultus	Goat R.	LaFrance	Lockhart	Summit	Combined
1929[a]				40,000					40,000
1930				No records					
1931			120,000						120,000
1932-45				No records					
1946	50,000		50,000			50,000	50,000		200,000
1947	50,000		50,000c			110,000			160,000
1948	50,000		50,000		100,000				200,000
1949	90,000		80,000		160,000	80,000			410,000
1950	100,000		60,000		80,000	30,000			270,000
1951	50,000		30,000		75,000	20,000			175,000
1952	30,000		30,000		30,000	20,000	20,000		130,000
1952-57				No records					
1958[b]		90,000			160,000				250,000
1959-1986				No records					
1987					400,000			100,000	500,000
1988[c]					400,000			100,000	500,000
1989-2004				No records					
2005		200,000	300,000		1,000,000			500,000	2,000,000
2006		175,000						210,000	385,000
2007		150,000	300,000		1,100,000				1,550,000
2008[d]		90,000	120,000		828,000			80,000	1,118,000
2008[e]		240,000	180,000		700,000			240,000	1,360,000

[a] Kootenay stock.
[b] Montana stock.
[c] Fry were planted.
[d] Eggs planted in the gravel using a flexible PVC pipe as in previous years.
[e] In 2008, additional eyed eggs were placed into tubes which were buried in the gravel.

selected for eyed egg plants were known to have historically supported spawning populations. Stream sites were chosen primarily on accessibility and habitat suitability. Specific sites for artificial "redds" were identified by experienced personnel based on their judgment of the likelihood of adequate over-wintering water depth and flow. Size (area) of redds varied depending on ease of excavation but were generally about 0.5 m deep, and 0.75 m x 1.5 m in area. A 5 cm flexible PVC pipe was laid on the stream floor of the excavated area with one end at the downstream of the excavated area and the other end protruding out of the water upstream of the excavated area. The pipe was then held in place with nearby large rocks (~ 5-15 cm). After securing the PVC pipe, smaller (< 3 cm) screened gravels were then laid over the larger rocks and pipe to the original level of the stream bed. Eggs were poured into the protruding pipe. As the pipe filled with eggs it was gradually pulled from the redd allowing the eggs to flow out the open end and disperse within the gravel. Occasionally eggs "leaked" out of the artificial redd and small gravel and fines were placed to hold the eggs in place. One exception to this methodology occurred in Idaho tributaries in 2006 when, due to the low number of available eggs, the eggs were released into deep pools and covered with fine substrate.

An alternate method was used to plant about half the eggs in the South Arm Kootenay Lake tributaries during 2008. Tubes filled with 30,000 to 35,000 eyed eggs per tube were placed in a trench in the substrate and then covered with additional gravel (Eva Schindler, Ministry of Environment, Nelson, BC, personal communication). Numbers of eyed eggs planted using the two methods are documented in Table 3.

Egg-to-fry survival of the egg plant efforts has not been well documented. Stainless steel canisters with 100 kokanee eggs have been placed in some of the Idaho tributary redds in recent years. The following spring, the canisters were recovered and the number of eggs remaining was counted to calculate hatching rates. Based on this information, hatching rates at four tributaries ranged from 0-50% in 2005 (Table 4). No canisters were placed in 2006 due to the low number of eggs available, but canisters placed in the four tributaries the following year indicate that hatching rates improved, ranging from 60-90% (Table 4). Preliminary results from the 2008 egg plants indicate even better survival rates. Improved egg survival may be related to a change in methodologies. The Kootenai Tribe of Idaho began constructing artificial redds perpendicular to the stream flow beginning in 2007 to improve intragravel flow. Prior to this, redds were typically excavated parallel to the stream channel.

Table 4. Estimated egg survival based on canisters placed in selected Idaho tributaries in 2005, 2007, and 2008. No canisters were placed in 2006 due to low number of available eggs. Data provided by Kootenai Tribe of Idaho.

	Idaho tributary						
Year	Boundary	Long Canyon	Parker	Trout (S. Fork)	Ball	Myrtle	Fisher
2005		50%	15%	0%		15%	
2007		80%	60-70%	90%		90%	
2008	95%	90%	90%	95%	90%		95%

LOWER KOOTENAI KOKANEE POPULATION INFORMATION

Escapement surveys

Ongoing annual kokanee escapement counts to South Arm (BC) and Kootenai River (Idaho) tributaries provide an important metric for evaluating enhancement and reintroduction efforts. Because the focus of South Arm fertilization has been the recovery of lower Kootenai fish stocks upstream in BC and Idaho, monitoring annual kokanee escapements along with supplemental egg plants provide a measure of success of restoration actions. Little data on South Arm and Kootenai tributaries exist except for sporadic kokanee escapement surveys. Historic data for South Arm streams were summarized by Andrusak and Fleck (2007).

Annual peak counts for most South Arm and Kootenai River tributaries were implemented in Idaho in 1996 (Table 5) and in British Columbia in 1994 (Table 6). In recent years, each stream was surveyed weekly from mid-August through September. Experienced staff walked each stream counting fish in sections of stream accessible to spawning kokanee. Frequency of stream counts increased during the first two weeks of September when peak spawning was anticipated. The highest number of kokanee counted in each stream was reported as the peak count for the season.

Peak spawner counts in the Idaho tributaries conducted by the Kootenai Tribe of Idaho indicate an increasing trend in escapements from 1996 to 2003 that could be a response to the 1997-1999 eyed egg plants. Subsequently the counts declined for the next two years, followed by a more rapid increase in escapements through 2008 (Table 5). The latter segment pattern of escapements corresponds temporally with resumption of eyed egg plants in 2003 (Table 2) and initiation of South Arm fertilization efforts in 2004 (Table 1).

In contrast, South Arm survey counts conducted by the British Columbia Ministry of Environment suggest a declining trend in escapements from 1996 to 2000 (Table 6). In subsequent years, combined escapement counts varied between 1 and 202 spawners. However, adults from the 2005 eyed egg plants are not expected to return to British Columbia tributaries until 2009.

Table 5. Peak number of adult kokanee salmon counted in Idaho tributaries, 1980-2008. Data in 1980 and 1981 taken from Partridge (1983), 1993 through 2005 from Schindler et al. (2007b) and subsequent data provided by the Kootenai Tribe of Idaho. NS indicates no survey was conducted.

	Idaho tributaries							
Year	Boundary	Smith	Long Canyon	Parker	Trout	Myrtle	Ball	Combined
1980	2,000	2,000	2,000	500	100	0	0	6,600
1981	1,100	600	1,600	350	50	50	50	3,800
1982-92	No records							
1993	0	NS	17	47	0	0	NS	64
1994-95	No records							
1996	0	0	0	0	0	0	NS	0
1997	0	0	3	0	0	NS	NS	3
1998	8	0	0	0	0	NS	NS	8
1999	38	0	0	0	0	NS	NS	38
2000	17	NS	30	7	0	NS	NS	54
2001	31	NS	25	0	7	NS	NS	63
2002	0	30	NS	30	0	NS	NS	60
2003	0	NS	40	55	0	0	NS	95
2004	9	NS	11	1	5	0	NS	26
2005	0	NS	0	3	0	0	NS	3
2006	0	NS	6	5	0	0	NS	11
2007	NS	200	150	10	325	2	100	787
2008	0	215	0	62	535	9	455	1,276

Table 6. Peak number of adult kokanee salmon counted in British Columbia tributaries, 1951-2008. Data through 2005 taken from Schindler et al. (2007b), 2006 through 2008 data provided Eva Schindler (Ministry of Environment, Nelson, BC personal communication).

	British Columbia tributaries												
Year	Craw-ford	Gray	LaFrance	Lock-hart	Akokli	Sanca	Boulder	Midge	Goat River	Summit	Corn	Cultus	Combined
1951					354								354
1952					172								172
1953-68						No records							
1969										3,100			3,100
1970										4,200			4,200
1971						No records							
1972						650	30		17,500	3,700			21,880
1973										1,400			1,400
1974										900			900
1975										1,750			1,750
1976										2,300			2,300
1977						No records							
1978										1,150			1,150
1979										2,050			2,050
1980										4,100			4,100
1981-85						No records							
1986		204	38	128	13	40	0		3,710	2,500			6,633
1987-88						No records							
1989										1,700			1,700
1990										0			0
1991										0			0
1992						6	3		20	30			59
1993						No records							
1994	2	0	0	0	100	4	0	0	0	0		0	106
1995	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	40	30	20	20	200	0	0	50	4	0		50	414
1997	0	100	3	1	150	7	0	0	0	0			261
1998	0	5	0	0	50	2	0	5	2	0			64
1999	0	20	2	0	20	2	0	0	0	0			44
2000	0	2	0	0	20	0	1		0	0			23
2001	0	8	0	0	6	0	0	33	0	0			47
2002	0	10	0	0	5	0	0		0	0			15
2003	5	35	0	0	151	8	0	0	2	1			202
2004	0	8	0	0	8	0	0	0	0	0	0	0	16
2005	0	0	0	0	1	0	0		0	0			1
2006	0	9	0	0	2	0	0		0	1			12
2007	8	40	0	3	4	0	0		0	0		100	155
2008	0	6	2	0	0	0	0		0	0			8

DISCUSSION AND RECOMMENDATIONS

Fertilization, egg plants, and habitat restoration have been implemented to increase kokanee production in the Kootenai Subbasin. Seeding streams with eyed eggs, combined with nutrient addition, would be expected to produce the most direct response, in terms of numbers juveniles (one to two years later) and returning adults (four years later). Measures of juvenile production in tributaries are not available. Peak spawner counts indicate a positive change in kokanee production in Idaho tributaries. The 2007 return was the first year expected from the larger eyed egg plants initiated in 2003, and likely benefited from South Arm and Kootenai River nutrient additions. In 2004, about twice as many eggs were planted in Idaho tributaries, and a corresponding increase in spawners was observed in 2008. This pattern suggests that carrying capacity for the Idaho populations as a group has not yet been met. However, results were not consistent among the Idaho tributaries.

No spawning kokanee were observed in Long Canyon Creek in 2008 although 150 were counted there in 2007, despite more eggs were planted in 2004 than in 2003. Unfortunately, egg to fry survival was not evaluated in 2004. Conditions that would have affected poor juvenile survival or adult migrant passage blockage (low lows, high temperatures, etc.) for Long Canyon Creek should be explored. The number of spawning kokanee counted in Myrtle Creek was minimal in 2007 and 2008 (2 and 9, respectively) following the planting of several hundred thousand kokanee eggs in 2003 and 2004. In contrast, 100 and 455 spawners were counted in Ball Creek, the next tributary downstream from Myrtle Creek, during 2007 and 2008 even though no kokanee eggs were planted there until 2008 (Table 2). Ball Creek was rarely surveyed prior to 2007 (Table 5), but a local landowner of 20 years indicated that he had never seen the numbers of kokanee as he did during the last 2 years. One plausible explanation is that spawners originating from the Myrtle Creek plants did not find suitable habitat there and sought it out in nearby streams. The lower section of Myrtle Creek lies within the Kootenai National Wildlife Refuge, where a management priority is flat water for waterfowl use. The lower 2.6 km of the stream lies within the historic floodplain and is subject to being backwatered by the Kootenai River (GeoEngineers 2005). Thereafter, the gradient increases rapidly and the substrate is dominated by large angular cobble and boulders that is not suitable for spawning. In contrast, Ball Creek includes a roughly 600 m long reach with adequate flow and small rounded cobble substrate used by spawning kokanee (GeoEngineers 2008, Jason Scott, GeoEngineers, Spokane, WA, personal communication). Because Ball Creek is the nearest tributary (Figure 1) that has suitable habitat, it is reasonable to hypothesize that kokanee originating from Myrtle Creek egg plants could now be using Ball Creek to spawn. Another possibility is that these fish originated from Lake Koocanusa tributaries, entrained through Libby Dam and reared downstream. These displaced fish may be spawning in lower Kootenai tributaries because they cannot migrate back to their natal streams.

In contrast to Idaho tributaries, kokanee returns to South Arm tributaries have not improved substantially in recent years despite nutrient additions to Kootenay Lake and the Kootenai River. One obvious difference was that no eggs were planted in South Arm tributaries between 1989 and 2004 while Idaho tributaries have had annual plants since 2003. The number of kokanee returning to South Arm tributaries in recent years was likely insufficient to sustain natural production. We expect that returns to South Arm tributaries will improve in 2009 as progeny from the 2005 egg plants mature.

Excessive entrainment of non-native kokanee from Koocanusa into the lower Kootenai River could affect efforts to re-establish self sustaining spawning populations in Idaho and South Arm tributaries. In the early 1990s, annual entrainment of kokanee through Libby Dam was estimated to be several million fish (Skaar et al. 1996), and anecdotal information suggests that hundreds of thousands of returning adults concentrated below Kootenai Falls in the past (Schindler et al. 2007b). These fish almost certainly reared in Kootenay Lake where they competed with native kokanee stocks. In contrast, the number of kokanee that can spawn in Idaho tributaries is limited by the quantity and quality of available habitat (Andrusak et al. 2004). Therefore, fry originating from Idaho tributaries may have a difficult time competing with greater orders of magnitude displaced fry. In addition, some fry planted in Buck and Moyie Lakes may also migrate downstream and rear in Kootenay Lake, although current stocking levels (Appendix A) are such that the magnitude of displaced fish is likely small.

We provide the following recommendations to promote and quantify successful re-introduction of sustainable kokanee populations into Idaho Kootenai River tributaries:

- Continue tributary eyed egg plants. Consider alternative methods such as streamside incubation boxes to improve and monitor egg to fry survival. Alternating techniques between adjacent tributaries/streams would help determine which technique produces better results.
- Continue South Arm and Kootenai River nutrient addition and monitoring programs.
- Consider and evaluate the use of in-stream perforated egg tubes for kokanee eye-egg introductions to increase incubation and emergence success.
- Continue and expand tributary habitat restoration and monitoring activities. Consider construction of one or more spawning channels in strategic locations in Idaho to help mitigate for loss of historic habitat.
- Continue monitoring tributary kokanee spawner returns. Consider alternative methods such as weirs or video techniques to enumerate escapement rather than index peak counts. Coupling monitoring with mark-recapture efforts (using visual or telemetry tags) may provide better estimates of spawner numbers.
- Consider tributary habitat modeling to assess current carrying capacities and quantify expected improvements due to potential habitat restoration options. This information will allow managers to identify most effective areas for restoration efforts.
- Consider an evaluation of juvenile production (i.e. add screw traps to allow mark-recapture estimators) to better define stream carrying capacity and the relationship between egg/juvenile/adult production.
- Collect annual flow and temperature information to better assess inter annual variation in kokanee returns.
- Quantify kokanee entrainment through Libby Dam.
- Develop and implement methods to quantify the number of adult kokanee milling below Kootenai Falls and in lower Lake Creek as a measure of kokanee entrainment.

- Obtain genetic samples from Bull Lake brood sources and lower Lake Creek spawners to assess Lake Creek Dam entrainment.

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REFERENCES

Anders, P.J. 1993. Kootenai River white sturgeon studies. Kootenai Tribe of Idaho. Job Completion report to the Bonneville Power Administration. Project No. 88-64. https://research.idfg.idaho.gov/Fisheries%20Research%20Reports/Volume%20155%20Article%2004.pdf

Anders, P., H. Andrusak, K. Ashley and J. Hammond. 2004. Kokanee and ecosystem restoration in South Arm Kootenay Lake and the Arrow Lakes Reservoir, British Columbia. Pre-implementation Report and Work Plan-FY 2003. Contract report prepared for the Kootenai Tribe of Idaho.

Anders, P., J. Faler, M. Powell, H. Andrusak, and C. Holderman. 2007. Initial microsatellite analysis of kokanee (*Oncorhynchus nerka*) population structure in the Kootenai/y River Basin, Idaho, Montana, and British Columbia. Prepared for Freshwater Fisheries Society of British Columbia and the Kootenai Tribe of Idaho. http://www.fishsciences.net/reports/2007/kokanee-genetics-report_2007-0700.pdf

Andrusak, H. 1981. Kootenay Lake sport fishery statistics 1978-80. Fisheries Technical Circular No 53 19181. Ministry of Environment. http://a100.gov.bc.ca/appsdata/acat/documents/r4070/FTC53_1140560685057_3429b8ec3dcd49aeab3bffbfce4b73eb.pdf

Andrusak, H., and C. Brown. 1987. Kootenay Lake fisheries management plan 1987-89. B.C. Ministry of Environment, 56 pp.

Andrusak, H., P. Slaney, and L. Fleck. 2004. Status of kokanee in the South Arm of Kootenay Lake and assessment of select tributary streams with restoration potential for spawning kokanee and rainbow trout. Redfish Consulting Ltd. Contract Report for the Kootenai Tribe of Idaho, Bonners Ferry, Idaho.

Andrusak, H., D. Sebastian, G. Scholten, and P. Woodruff. 2007. Response of kokanee to experimental fertilization of the North Arm of Kootenay Lake in 2005. *In* Schindler et al. (2007b).

Andrusak, H and L. Fleck. 2007. Status of kokanee in the south arm of Kootenay Lake prior to experimental fertilization, 2004. *In* Schindler et al. (2007a).

Ashley, K., and L. Thompson. 1993. Kootenay Lake fertilization experiment. Year 1 (1992/93) report. Fisheries Project Report No. RD 32, Ministry of Environment, Lands and Parks, Province of British Columbia.

Ashley, K., L.C. Thompson, D. C. Lasenby, L. McEachern, K.E. Smokorowski and D. Sebastian. 1997. Restoration of an interior lake ecosystem: the Kootenay Lake fertilization experiment. Water Qual. Res. J. Canada, 1997. Volume 32 No. 295-323.

Ashley, K., L. C. Thompson, D. Sebastian, D. C. Lasenby, K. E. Smokorowski and H. Andrusak. 1999. Restoration of Kokanee Salmon in Kootenay Lake, a Large Intermontane Lake, by Controlled Seasonal Application of Limiting Nutrients. In Murphy, T. P., and M. Munawar. 1999. *Aquatic Restoration in Canada.* Backhuys Publishers, Leiden, 1999.

Bull, C.J. 1964. Enumeration of kokanee salmon populations on the Lardeau-Duncan River system 1964. Brit. Col. Fish and Wildlife Branch, Fisheries Management Report 46. http://a100.gov.bc.ca/appsdata/acat/documents/r715/20063_1074125653015_2bf9d411f1bf49839377ed1d9f88f61f.pdf

Dalbey, S., J. DeShazer, L. Garrow, G. Hoffman, and T. Ostrowski. 1998. Quantification of Libby Reservoir water levels needed to maintain or enhance reservoir fisheries, Project No. 1983-46700, BPA Report DOE/BP-12660-7. 132 p. http://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=12660-7

Daley, R.J., E.C. Carmack, C.B.J. Gray, C.H. Pharo, S. Jasper, and R.C. Wiegand. 1981. The effects of upstream impoundments on Kootenay Lake, BC Canada Inland Waters Directorate, Research Institute, Scientific Series, West Vancouver, British Columbia.

Duke, S., P. Anders, G. Ennis, R. Hallock, J. Hammond, S. Ireland, J. Laufle, L. Lockard, B. Marotz, V. Paragamian, and R. Westerhof. 1999. Recovery plan for Kootenai River white sturgeon (*Acipenser transmontanus*). Journal of Applied Ichthyology (15):157-163.

Dunnigan, J.L. 2002. Kootenai River fisheries monitoring results from the spill events at Libby Dam, June-July 2002. Montana Fish Wildlife and Parks report.

Dunnigan, J.L., J. DeShazer, L. Garrow, B. Marotz, T. Ostrowski, M. Benner, and B. Marotz. 2008. Mitigation for the construction and operation of Libby Dam: Libby Mitigation Program, 2006 annual progress report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

GeoEngineers. 2005. Baseline habitat and vegetation conditions, Bonners Ferry, Idaho. File no. 9229-004-00. Spokane WA.

GeoEngineers. 2008. Ball Creek trophic study, Boundary County, Idaho. File no. 9229-002-03. Spokane WA.

Hoffman, G., B. Marotz, J. DeShazer, L. Garrow, T. Ostrowski and J. Dunnigan. 2002. Mitigation for the construction and operation of Libby Dam: Annual report 2000. Bonneville Power Administration. Portland, Oregon. Project Number 199500400. http://pisces.bpa.gov/release/documents/documentviewer.aspx?pub=R00006294-3.pdf

Holderman, C., G. Hoyle, R. Hardy, P. Anders, P. Ward, and H. Yassien. *In prep*. Libby Dam hydro-electric project mitigation: Efforts for downstream ecosystem restoration. Proceedings of EWRI Conference, Bangkok, Thailand.

Knudson, K. 1994. Water quality status report: Kootenay (Kootenai) River Basin British Columbia, Montana and Idaho. Kootenai River Network, Libby MT., and Ecological Resource Consulting, Helena MT. 57 pp.

Kootenai Tribe of Idaho and Montana Fish, Wildlife and Parks (KTOI and MFWP). 2004. Kootenai Subbasin Plan. Part I: Kootenai River Subbasin Assessment. A report prepared for the Northwest Power and Conservation Council. Portland, OR. http://www.nwcouncil.org/fw/subbasinplanning/kootenai/plan/

Kootenai Tribe of Idaho (KTOI) and G. Kruse. 2002. Trout Creek biological assessment: 2001. A report prepared for the Bonneville Environmental Foundation. 64 pp.

http://www.krisweb.com/kriskootenai/krisdb/html/krisweb/biblio/kootenai_bef_kootenaitribeetal_2001_troutcreekba.pdf

Kruse, G. 2005. Myrtle Creek biological assessment: 2004 Phase II final report. Report prepared for U.S. Fish and Wildlife Service, Kootenai National Wildlife Refuge, Bonners Ferry, ID.

Kruse, G. 2007. Kootenai River model watershed restoration project: Baseline report 2002-2006. Draft report prepared for Kootenai Tribe of Idaho and Bonneville Environmental Foundation. 141 pp.

Larkin, G.A. 1998. Kootenay Lake phosphorus loading from the Kootenay and Duncan Rivers. Report prepared for the Columbia Basin Fish and Wildlife Compensation Program, 26 p.

Marotz, B., R. Sylvester, J. Dunnigan, T. Ostrowski, J. DeShazer, J. Wachsmuth, M. Brenner, M. Hensler, and N. Benson. 2007. Incremental analysis of Libby Dam operation during 2006 and gas bubble trauma in Kootenai River fish resulting from spillway discharge: Incident report on Libby Dam spill June 2006. Montana Fish, Wildlife and Parks report to Bonneville Power Administration. Portland, Oregon. 41 p.

Martin, A.D., and T.G. Northcote. 1991. Kootenay Lake: An inappropriate model for *Mysis relicta* introduction in north temperate lakes. American Fisheries Society Symposium 9:23-29.

Northcote, T.G. 1972. Some effects of mysid introduction and nutrient enrichment on a large oligotrophic lake and its salmonids. Verh. Internat. Verein. Limnol. 18:1096-1106.

Northcote, T.G. 1973. Some impacts of man on Kootenay Lake and its salmonids. Great Lakes Fisheries Commission Tech. Rep. 25. http://a100.gov.bc.ca/appsdata/acat/documents/r753/20020_c2_1074283671337_f21c593568bb42e993d3ef6a78ae99f6.pdf

Northcote, T.G. 1991. Success, problems and control of introduced Mysid populations in lakes and reservoirs. American Fisheries Society Symposium 9:5-16.

Northern Lights Inc. 2008. Application for license for a major water power project 5 MW or less Lake Creek hydroelectric project (FERC Project No. 2594). Draft License Application. http://www.norlight.org/LCRelicensing/docs/index.htm

Oliver, G. 1980. Sportfish creel census - Libby Reservoir, 1979. B.C. Ministry of Environment, 23 pp. http://a100.gov.bc.ca/appsdata/acat/documents/r707/20087_1074120341849_2bf9d411f1bf49839377ed1d9f88f61f.pdf

Partridge, F. 1983. Kootenai River fisheries investigations in Idaho. Idaho Department of Fish and Game. Completion Report. Boise, ID. https://research.idfg.idaho.gov/Fisheries%20Research%20Reports/Volume%2054_Article%2001.pdf

Perrin, C.J, 1988. Fertilization of Kootenay Lake West Arm for salmonid enhancement: 1987 monitoring and test of food limitation. B.C. Ministry of Environment and Parks, Fisheries Branch, Nelson, B.C. http://a100.gov.bc.ca/appsdata/acat/documents/r840/20986_1075146485896_2cff18b2858b4ea3bf20b24897f32a0c.pdf

Reeve, T., J. Lichatowich, W. Towey, and A. Duncan. 2006. Building science and accountability into community-based restoration: Can a new funding approach facilitate effective and accountable restoration? Fisheries 31:17-24.

Reeve, T. and W. Towey. 2007. A long-term, monitoring-intensive approach to Pacific Northwest watershed restoration. Ecological Restoration 25:73-74.

Rieman, B.E. and D.L. Myers. 1992. Influence of fish density and relative productivity on growth of kokanee in ten oligotrophic lakes and reservoirs in Idaho. Trans. Am. Fish. Soc. 121:178–191.

Schindler, E.U., R. Rae, K.I. Ashley, L. Vidmanic, D. Sebastian, H. Andrusak, G. Scholten, P. Woodruff, J. Stockner, F. Pick, L.M. Ley, P.B. Hamilton, G.F. Andrusak and L. Fleck. 2007a. Kootenay Lake Fertilization Experiment, Year 13 (North Arm) and Year 1 (South Arm) (2004) Report. Fisheries Project Report No. RD 117, Ministry of Environment, Province of British Columbia. http://a100.gov.bc.ca/appsdata/acat/documents/r11394/KLFExperiment,Years13(NorthArm)andYear1(SouthArm)_1197930490456_8e248a68ce5aa62397a394c4935821a961e1d998cc8.pdf

Schindler, E.U., H. Andrusak, K.I. Ashley, G.F. Andrusak, L.Vidmanic, D. Sebastian, G. Scholten, P. Woodruff, J. Stockner, F. Pick, L.M. Ley, and P.B. Hamilton. 2007b. Kootenay Lake fertilization experiment, year 14 (North Arm) and year 2 (South Arm) (2005) report. Fisheries Project Report No. RD 122. http://a100.gov.bc.ca/appsdata/acat/documents/r11437/KLFExperiment,Years14(NorthArm)andYear2(SouthArm)_1199724708943_8e24f5b7ce596031506f176421fb907fc349264c279.pdf

Sebastian, D.C., H. Andrusak, G. Scholten, P. Woodruff and G.F. Andrusak 2007. Response of kokanee to experimental fertilization of the North Arm of Kootenay Lake in 2005. *In* Schindler et al. (2007b).

Skaar, D., J. DeShazer, L. Garrow, T. Ostrowski, and B. Thomburg. 1996. Quantification of Libby Reservoir levels needed to maintain or enhance reservoir fisheries: Investigations of fish entrapment through Libby Dam, 1990-1994. Prepared for Bonneville Power Administration. http://nsdl.org/resource/2200/20061004180438371T

Snyder, E.B. 2001. The effect of anthropogenic alteration on large river structure and function measured by algal response to nutrient regime, ecosystem metabolism, carbon cycling, and energy flow. Dissertation. Idaho State University. December 2001

Snyder, E.B. and G. W. Minshall. 1994. Ecosystem metabolism and nutrient dynamics in the Kootenai River in relation to impoundment and flow enhancement for fisheries management. Annual Report. Stream Ecology Center, Idaho State University, Pocatello ID.

Snyder, E.B. and G. W. Minshall. 1995. Ecosystem metabolism and nutrient dynamics in the Kootenai River in relation to impoundment and flow enhancement for fisheries management. Annual Report. Stream Ecology Center, Idaho State University, Pocatello ID.

Snyder, E. B. and G. W. Minshall. 1996. Ecosystem metabolism and nutrient dynamics in the Kootenai River in relation to impoundment and flow enhancement for fisheries management. Project Completion Report. Stream Ecology Center, Idaho State University, Pocatello ID.

Snyder, E. B. and G. W. Minshall. 2005. An energy budget for the Kootenai River, Idaho (USA), with application for management of the Kootenai white sturgeon, Acipenser transmontanus. Aquat. Sci. 67 (2005) 472 – 485

U.S. Department of Interior, Fish and Wildlife Service (USFWS) 1999. White Sturgeon; Kootenai River population recovery plan. Region 1, USFWS, Portland, Oregon.

Vernon, E. H. 1957. Morphometric comparison of three races of kokanee (*Oncorhynchus nerka*) within a large British Columbia lake. Journal of the Fisheries Research Board of Canada 27: 1239-1250.

Westover W.T. 2003. Koocanusa kokanee enumeration (2003). Ministry of Water, Land and Air Protection, Province of British Columbia. Cranbrook, BC. http://a100.gov.bc.ca/appsdata/acat/documents/r673/koocanusakokaneeenumeration2003_1073667957565_12d976cd2e724dfc9482b3fa2ad9766e.pdf

Woods, P. F. 1982. Annual nutrient loadings, primary productivity, and trophic state of Lake Koocanusa, Montana and British Columbia, 1972-80. Geological Survey Professional Paper 1283, United States Government Printing Office.

APPENDIX A: LAKE KOOCANUSA AND KOOTENAI RIVER TRIBUTARY KOKANEE STOCKING RECORDS

Appendix Table 1. Kokanee statistics from the Kootenay Hatchery record, 1970 to 1980 (Data from a 1992 memo from C. P. Brown, B.C. Ministry of Environment).

Brood year	Release year	Brood stock source	No. at start of rearing	No. of moribund fish flushed down the drain	No. released to stocking list
1969	1970	Chilliwack, Okanagan. River, and 50,000 Lamb Creek stock	888,000	157,000	731,000
1970	1971	Chilliwack	600,000	273,000	327,000
1971	1972		No kokanee reared		
1972	1973	Okanagan River	485,000	302,000	183,000
1973	1974	Okanagan River	770,000	488,000	282,000
1974	1975		No kokanee reared		
1975	1976		No kokanee reared		
1976	1977	Meadow Creek	188,000	112,000	76,000
1977	1978	Meadow Creek	129,000	34,000	95,000
1978	1979	Meadow Creek	201,000	101,000	100,000
1979	1980		No kokanee reared		
			Total	**1,467,000**	

Appendix Table 2. Number of kokanee stocked into Moyie Lake, BC, 1942-2008. Data downloaded from the B.C. Ministry of Environment website: http://www.env.gov.bc.ca/fish/.

Date released	Number released	Stock	Hatchery	Average Wt	Life Stage
1/1/42	75,000	Meadow Creek	Nelson Hatchery		Eyed egg
1/1/43	100,000	Meadow Creek	Nelson Hatchery		Eyed egg
1/1/44	100,000	Meadow Creek	Nelson Hatchery		Eyed egg
1/1/45	100,000	Meadow Creek	Nelson Hatchery		Eyed egg
1/1/46	100,000	Meadow Creek	Nelson Hatchery		Eyed egg
1/1/47	50,000	Meadow Creek	Nelson Hatchery		Fry
1/1/48	100,000	Meadow Creek	Nelson Hatchery		Eyed egg
1/1/49	50,000	Meadow Creek	Nelson Hatchery		Eyed egg
1/1/51	40,000	Meadow Creek	Nelson Hatchery		Eyed egg
5/1/84	7,500	Norbury Creek	Kootenay Hatchery	2	Unknown
4/29/96	100,000	Meadow Creek	Loon Creek Hatchery	1.1	Fry
4/30/97	100,000	Meadow Creek	Loon Creek Hatchery	1	Fry
5/17/99	100,000	Meadow Creek	Clearwater Hatchery	3.5	Yearling
5/10/00	92,000	Meadow Creek	Clearwater Hatchery	3.2	Fingerling
5/1/02	29,000	Meadow Creek	Clearwater Hatchery	3.1	Fingerling
5/5/03	46,000	Deka/Sulphurus Lakes	Clearwater Hatchery	3.3	Fingerling
5/17/04	46,000	Meadow Creek	Clearwater Hatchery	3.7	Fingerling
5/16/05	46,000	Meadow Creek	Clearwater Hatchery	2.6	Fingerling
5/17/06	46,000	Meadow Creek	Clearwater Hatchery	2.8	Fingerling
5/10/07	45,962	Norbury Creek	Clearwater Hatchery	3.4	Fry
5/8/08	46,000	Norbury Creek	Clearwater Hatchery	3.4	Fry

Appendix Table 3. Number of kokanee fry planted in Bull Lake, Montana, 1953-2007. Data provided by Jim Dunnigan, Montana Fish Wildlife, and Parks, Libby, MT.

Year	Month	Brood stock source	Number released
1953	April	unknown	100,000
1954-60		No records	
1961	March	unknown	112,850
1962	April	unknown	159,100
1963	April	unknown	139,376
1964	March	unknown	134,592
1965	April	unknown	102,000
1966	April	unknown	116,496
1967-70		No records	
1971	April	unknown	182,700
1972	April	unknown	200,000
1973	May	unknown	200,000
1974	May	Swan Lake	230,000
1975	May	Swan Lake	200,000
1976	May	Flathead Lake	200,000
1977	April	Lake Mary Ronan	150,000
1978	May	Flathead Lake	350,000
1979	April	Lake Mary Ronan	200,000
1980	May-June	Flathead Lake	190,000
1981	June	Flathead Lake	30,000
1982	June	Flathead Lake	50,000
1983	June	Granby Reservoir, CO	100,000
1984	May	Lake Mary Ronan	99,890
1985	June	Flathead Lake	100,000
1986	June	Flathead Lake	212,515
1987	June	Lake Mary Ronan	53,900
1988	June	unknown	50,000
1989	May	unknown	50,512
1990	May	Lake Mary Ronan	99,631
1991	June	unknown	98,155
1992-93		No records	
1994	May	Lake Mary Ronan	50,460
1995	May	Rereg Reservoir	12,188
1995	May	Swan Lake	80,256
1996	May	Lake Mary Ronan	50,400
1997	April	Lake Mary Ronan	50,688
1997	April	Wyoming	48,640
1998	April	Swan Lake	101,624
1999	June	Little Bitterroot Lake	32,412
1999	June	unknown	23,638
2000	April-May	Little Bitterroot Lake	172,995
2000	May	Lake Mary Ronan	41,088
2001	March	Lake Mary Ronan	25,520
2001	March	Little Bitterroot Lake	172,344
2002	April	Lake Mary Ronan	170,060
2003	May	Lake Mary Ronan	98,000
2004	April	Little Bitterroot Lake	102,652
2006	April-May	Lake Mary Ronan	115,200
2007	May	Lake Mary Ronan	43,200
2007	May	Little Bitterroot Lake	43,200

APPENDIX B: KOOTENAI RIVER FERTILIZATION MONITORING PROGRAM KOKANEE DATA.

Appendix Table 4. Number of samples and length statistics of kokanee captured in the Kootenai River as part of the fertilization monitoring program, 2002-2007. Data provided by Charlie Holderman, Kootenai Tribe of Idaho.

Year	Site	Number of samples	Length (mm) Minimum	Mean	Maximum	SD
2002	KR4	1	237	237	237	
	KR6	7	217	246	284	24
	KR9	8	213	252	270	19
	KR10	2	174	181	187	7
2003	KR4	1	75	75	75	
	KR6	6	228	239	256	9
	KR9	1	231	231	231	
	KR10	4	210	221	230	7
2004			None sampled			
2005	KR4	2	238	247	256	9
	KR6	7	230	246	260	10
	KR9	7	212	236	252	12
	KR10	8	228	242	251	8
	KR14	62	205	240	302	20
2006	KR4	1	75	75	75	
	KR6	12	254	274	303	13
	KR9	2	260	266	272	6
2007			None sampled			