Summary of Findings

Sport fishery creel surveys were conducted on Spada Lake in 1979-80, 1985 through 1989, 1992, and 1995. Fish sampling occurred on the lake and in the tributaries between 1995 and 1997, with most fish being sampled from the lake in 1997. The reservoir was sampled quantitatively for zooplankton between early April and mid–November of 1997. This report is a synthesis of these surveys, and makes recommendations for future management of the reservoir and its fishery.

Individual report segments end with a listing of conclusions that are specific to each unit. This report segment is a more general overview of the project's conclusions. The reader should review individual report segments for more detail.

Creel Survey

Catch, Harvest, and Effort

Total game fish harvest increased five or six–fold (20,243 trout) after the raising of Culmback Dam (Project Stage II), but decreased to 2.1 percent of its 1985 level in 1995 (422 trout). A 78 percent drop in harvest between 1989 and 1995 was not caused by a change in regulations. Sharply reduced harvest rates are attributed to a scarcity of legal–sized fish (≥12 inches).

Catch rates have held fairly constant since 1986, since the number of trout <12" appears to be relatively high, and total catch includes fish voluntarily released.

Angler effort (number of trips) on the lake has declined almost continuously since 1985. Effort in 1995, the last surveyed season, was lower than during Stage I, at just over one trip per surface acre, or 2002 trips in 1995. The 1995 effort level was 15.4 percent of that seen in 1985.

Water Quality

Dissolved oxygen in the reservoir is at near–saturation levels for much of the year (based primarily on samples taken near the dam), but a zone of reduced oxygen content occurs in the old river channel just upstream of the dam. The dimensions of this zone are poorly documented, but are probably not large.

The lake is isothermal at about 3° C in mid–winter, and warms to 21° to 22° C by early August. The thermocline is only weakly developed due to the reservoir's very high turnover rate (3.4/yr). A metalimnion occurs between 6 and 9 meters (20 to 30 feet).

The 1997 heat budget (20,320 cal/cm^2) was the highest in the years 1989 through 1997, but was nevertheless below both median and mean values for lakes of similar size, elevation, and latitude.

Mineral turbidity is an important occurrence, particularly in the spring. Secchi transparency begins with a low of about 1.5m (5 ft) at that time, peaks in late June at about 4.9m (16 ft), and diminishes during a late August-September phytoplankton pulse to about 2.7m (9 ft).

The euphotic zone was estimated to range from 13.7m (45 ft) in June to 7.6m (25 ft) in September. The mean monthly euphotic zone between June and September was 9.3m (30.4 ft). These estimates suggest Spada Lake is roughly equivalent to other reservoirs that have been shown to be highly oligotrophic and unproductive.

Historic and present conductivity levels in Spada Lake average 20.6 μS/cm. Water column pH values ranged from 6.1 to 7.4, and averaged 6.68.

Secondary Production

Zooplankton

Of 12 cladocerans identified from Spada Lake, only *Daphnia rosea* was seasonally important in the trout diet. *Epischura nevadensis* was the only copepod eaten, and then only occasionally. *Holopedium gibberum* was the numerically most important plankter, but did not contribute to the trout diet in a meaningful way. *Holopedium* constituted 75 to 95 percent of the plankton for much of the year. *Daphnia* and *Epischura* were the only important edible species.

Cyclopoid copepods were far less abundant in Stage II than in Stage I, probably due to reservoir aging. Although comparisons with Stage I were very difficult due to differing methods, *Holopedium* appeared to be roughly 70 percent less abundant, *Daphni*a is approximately unchanged, and *Bosmina* is about 20 percent of its Stage I density.

Total crustacean zooplankton density in the reservoir's top 15 feet (12,500 to 16,000 individuals/m^3), when used as an indirect measure of primary production, is similar to, or higher than that seen in other area lakes and reservoirs having similar putative low potential production. The growing season extended from early May through mid– or late October.

The mean density of edible zooplankton was 1440/m^3. The mean percent of edibles between mid–July and mid–October was 31 percent of the total crustacean zooplankton, which is representative of an oligotrophic system.

The overwhelming abundance of *Holopedium* relative to *Daphnia*, plus the near–absence of *Diaptomus*, may be a reflection of excessive planktivory. The fish population (trout plus brown bullheads) is probably too numerous for the level of planktonic secondary productivity. Low phytoplankton (primary) production is the ultimate cause of food shortages.

Daphnia was clearly the most important rainbow and cutthroat dietary species. However, due to its small size, only about one half of the *Daphnia* in Spada are suitable as trout food.

Spada Lake in Stage II is oligotrophic, and is expected to remain at that level. Nutrients added by soils flooded in 1985 have probably been exhausted due to ongoing sedimentation into the deeper parts of the reservoir, and earlier removal in intensive fisheries in the mid– to late 1980s.

<u>Benthos</u>

Chironomid densities in the drawdown zone appeared to be roughly equivalent to Stage I levels. Oligochaete densities appeared to be higher in Stage II, but these invertebrates were not eaten by trout.

Both midges and segmented worms may be at above–average levels in Spada when compared with other area reservoirs.

Leeches and clams are minimally present in the trout diet, but are still present in certain zones or locations within the reservoir.

There was no apparent loss or gain of invertebrates species between Stages I and II, given the very low level of sampling to date.

Benthic sampling data collected in 1997 should be used to design more complete surveys in future years.

Tertiary Production

<u>Fish Relative Abundance</u>

One half of all trout collected were rainbow; somewhat less than one third were cutthroat, and about one fifth were hybrids. A subsample of those fish $\geq$12" yields species proportions very similar to that seen in the 1986 and 1992 sport fisheries.

Horizontal gillnet catch per unit effort was higher than that of vertical gillnets in four of six sampling months. Floating gillnets outfished sinking horizontals set from the shore's edge.

Brown bullheads were collected in all gear types, even offshore, but most were taken in the horizontal nets set from shore.

Trout were always taken from near the surface in vertical nets, but their maximum collection depth increased as the reservoir warmed, then retracted towards the surface in the fall. The deepest trout collected was at 68 ft (20.7m). There was no evidence that older, larger trout preferred deeper water.

Length Frequencies

Length frequencies of trout collected correlated closely with length–at–age data. Most trout sampled were Age 1 to 3, with older trout being relatively scarce. Trout larger than 32 cm (12.5") were rare.

Sex Ratio

The sex ratio in 1996-97 tended to favor females an average of 2.5 percent.

Trout Immigration, Mortality, Population Size, and Standing Stock

Immigration

A preliminary, indirect estimate of immigration in 1997 ranged from 0.56 to 2.5 trout/acre. A more definitive assessment needs to be made, either by mark-recapture methods, or tributary trapping.

Mortality

Annual mortality (fishing + natural) for all trout combined was estimated as 45.2 percent in 1997.

Population Size

Two trout population estimates were made, one based on gillnet catch per unit effort, the other on the relationship between angler catch rate and trout density (Ross Lake model). These ranged from 2,269 to 10,162. The latter figure is more reasonable, but may still be low, at 5.4 trout/acre.

Standing Stock

Based on the larger trout population estimate and the length:weight relationship, trout standing stock in 1997 was estimated as a little less than 1.0 lb/ac. Based on Spada's water chemistry and morphometry, and models from other reservoirs, standing stock should be closer to 40 lbs/ac. The difference is probably due to an erroneous trout population estimate, and/or the lack of an estimate of brown bullhead biomass.

Trout Age, Growth, Condition, and Internal Fat

Age and Growth

Annual incremental growth of trout Age 3 or older was significantly lower in 1997 than five years earlier. Trout growth rates in Spada are lower than most other area reservoir trout populations.

Condition and Internal Fat

Relative weights of both rainbow and cutthroat were almost universally below the median, or "good" value of 100 established for this index. Only rainbow showed a slight increase in relative weight over the summer.

The 1997 trout samples showed sharp declines in both relative weight and relative condition (two separate indices) after 11 to 12 years of reservoir aging.

Ninety three percent of all trout sampled from Spada Lake in 1997 held little or no internal fat. Both rainbow and cutthroat showed a decrease over the summer in the percentage of fish with no fat, but 55 percent of all trout in late October to early November had little or no internal fat.

Trout Food Habits

Larger invertebrate food resources in Spada Lake have been reduced or eliminated in the drawdown zone.

Preferred cladoceran zooplankton species (*Daphnia*) are only suitably abundant and large to elicit a trout feeding response for a few weeks of the year. Zooplankton occurred more frequently in rainbow stomachs than in cutthroat or hybrids.

Although almost all trout were obtaining some food between early April and mid-October, internal fat levels were extremely low, as was relative weight for most trout age groups. Only about 6 percent of all stomachs sampled were judged to be full; a running biweekly mean of degree of fullness was always less than 50 percent.

Trout diets are currently based predominantly on midge pupae or larvae, supplemented with terrestrial insects and stone– or caddisfly nymphs. Zooplankton (cladocerans) is less important throughout the year, except it is somewhat more important for rainbow, particularly during the July-September period.

Spawning Period and Age at Maturity

The spawning period of trout in Spada Lake is approximately mid–February through the first week in June. Cutthroat spawning may end of a week or two earlier than rainbow or hybrid trout.

Most cutthroat mature at Age 3 in Spada Lake, as do a majority of the rainbow. There appears to have been a reduction in mean age at maturity, particularly for rainbow (2.7) and hybrids.

Changes in length at first maturity in 1997 versus past years could not be demonstrated, largely due to differences in the methods used to document age and length at spawning.

The mean length of ripe trout collected off stream mouths in the spring of 1997 was 26.1 cm for cutthroat, and 22.0 cm for rainbow.

Trout Parasitism and Mortality

Rainbow, cutthroat, and their hybrids were found to be infected with *Diphyllobothrium ditremum*. Prevalence of the parasite varied seasonally in all three trouts, ranging from 10 to 100 percent overall, but was between 50 and 100 percent in mid–November.

Declines in prevalence within a single species and age group over the summer was interpreted as mortality.

Infection intensity varied greatly, with plerocercoid counts ranging from 0 to 185 in individual fish. First–year reservoir residents built infections to a mean mid–summer peak of 27 plerocercoids/fish, but declined to a fall level of 4/fish. Patterns of intensity over the sampling period varied between the trout life history groups, with first–year reservoir residents potentially suffering greatest mortality.

Cutthroat tended to exhibit lower infection intensities than either rainbow or hybrid trout. When considered on a seasonal basis, this difference may also indicate a greater susceptibility to mortality.

The infection intensities observed are sufficient to cause mortality, particularly for trout in relatively poor condition. Relative weight reached or exceeded 100 only in trout that harbored no plerocercoids. There was a generally consistent negative correlation between plerocercoid counts/fish and the amount of internal body fat. Fat content dropped to trace or non–existent levels in trout bearing more than five or six plerocercoids.

The final host for *D. ditremum* in Spada Lake was not confirmed, and could be one or more species of piscivorous bird or mammal.

Options with the most promise for indirect control of the parasite in the fish community include a change in the fish species mix, and lake fertilization or other enhancement of the invertebrate prey base to effect a dietary shift away from copepods. A dietary shift may be facilitated by control of brown bullheads, if the latter are shown to be a major competitor for relatively scarce food resources.

Fish Harvest (Yield) and Recreational Use Levels

Fishery Yield

Estimated fishery yield (annual weight of trout harvested/unit area) nearly tripled at the outset of Stage II, but then declined to 3.2 percent of the level seen in 1979-80 (Stage I), and 1.1 percent of that seen in 1985.

Current Stage II water chemistry and reservoir morphology suggest a sustainable annual yield of 1.15 kg/ha (1.03 lbs/ac). This represents an estimated 24 percent reduction from Stage I on a per unit area basis, but reservoir enlargement in Stage II increased overall potential yield 76 percent from Stage I.

Attainment of 1.15 kg/ha in the fishery is nearly impossible under the current 12" minimum size regulation. Harvest of smaller, younger age classes of trout will allow an increase in fishery yield, but the negative impact on spawning escapement cannot be assessed without a more accurate trout population estimate, and/or additional trout life history information to allow modeling of various fishery strategies.

Recreational Use (Fishing Effort) Levels

Harvest of a preliminary estimate of 6,450 younger trout would cap effort levels at 1.73 trips/acre, or 3,225 trips/yr if all parties harvested two trout per outing.

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Fishery Management Recommendations and Attainment of Management Objectives

Wild trout fisheries can be extremely valuable (Connelly and Brown 1991; Loomis and White 1996). Wild cutthroat that are repetitively caught in the Yellowstone River are worth up to $46 apiece (Gresswell 1985), vastly more than their immediate hatchery replacement costs. Using a general figure of $26.36 for the "economic impact" of a day's trout fishing in Oregon (The Research Group 1991), the following table of economic values can be generated for past naturally–produced trout fisheries on Spada Lake:

Year	Number of Trips	Economic Value
1985	12,994	$342,522
1986	10,079	$265,282
1987	6,769	$178,431
1988	3,385	$ 89,229
1989	4,619	$121,757
1992	3,584	$ 94,474
1995	2,002	$ 52,773

These figures represent a potential lost economic benefit to the area economy of almost $290,000 per year (1985 v. 1995). While a fishery capped at the reservoir's theoretical yield ceiling would be about 3,225 trips/yr worth about $85,000, the 1985 effort level could be reached by anglers practicing strict catch and release. For this reason, we feel additional research and monitoring should be directed to assuring that most of the fishery management goals and objectives for Spada Lake are attained.

Attainment of Management Objectives

The goals and objectives listed in Background — Relationships to Current Fishery Management Goals and Objectives are reiterated below, plus the relevant study results and associated recommended management steps, with discussion as necessary. Most of these were developed directly from the Goals, Policies and Objectives of the Washington Fish and Wildlife Commission (WDW 1991; WDFW 1995).

Goal 1. *Maintain abundant wild fish for consumption*

The (current) lack of harvestable trout is due to a lack of fish larger than the current minimum size (12"). However, that in turn is caused by a combination of high natural mortality due to

Diphyllobothrium, as well as angling. We feel natural mortality is currently much more important than angling losses of larger, older trout.

Intense fishing pressure under a minimum size can eliminate the older age groups in a population, leaving mostly fish at or slightly below the minimum size. A ***maximum*** size limit, however, if complied with, will protect older (larger) trout which escape the fishery. This has worked very well with Yellowstone cutthroat (Gresswell 1980). Protection of older, larger fish will also help prevent selection against faster–growing fish (genetic benefits). Currently, fish which may exhibit faster growth, perhaps linked with resistance to *Diphyllobothrium*, are subject to harvest sooner. Our 1997 field data showed more larger, older cutthroat than rainbow or hybrids. The largest, oldest fish, an Age 6+, 22.5" (57cm) female, was a cutthroat, and demonstrates the potential for trout growth in Spada Lake, even under current conditions.

Overall trout abundance seems to be relatively high, based on trout surfacing activity seen on the lake. Our population estimates indicate otherwise, but could be subject to a sampling bias.

Recommendations:

Implement a 12" maximum size limit (all fish 12" or larger in total length must be released).

Obtain a more accurate estimate of reservoir trout abundance through a mark-recapture procedure.

Measure trout fry or fingerling immigration levels into the reservoir, and relate to a known spawning escapement (and estimated egg deposition).

Goal 2. *Maintain diversity and reasonable abundance of wildlife.*

Rainbow are probably less well–suited to Spada Lake than cutthroat, mainly due to a greater propensity for planktivory, hence susceptibility to infection with *Diphyllobothrium* (Pentec 1993).

The proportion of "pure" cutthroat in Spada Lake has steadily declined over the past decade. While it is highly unlikely that future hybridization can be prevented, any supplementation *for the purpose of building the wild trout stocks* in Spada should be done with native coastal cutthroat. The South Fork Tolt Reservoir stock is probably ideal for this purpose. That stock exhibits excellent growth, longevity, and to our knowledge has not been exposed to introgression with hatchery stocks. While the genealogy of both Spada and Tolt cutthroat is uncertain, both occur in the Snohomish River basin and are likely to be closely related.

Recommendations:

Perform genetic stock identification analysis on cutthroat from both Spada Lake and Tolt Reservoir.

Use South Fork Tolt Reservoir coastal cutthroat for future brood stock purposes in supplementing cutthroat trout in Spada Lake.

Goal 3. *Emphasize native species and natural production, but stocking is permissible.*

Our preliminary trout population estimates suggest that recruitment may be inadequate. A marked fish study would be extremely valuable to both estimate the overall trout population, but also obtain more refined estimates of annual mortality and recruitment (Ricker 1975). In addition, monitoring of the fishery after a major hatchery trout release would give a strong indication of the relative benefits (if any) of returning to that management approach.

Recommendation:

Release a suitably large number of marked trout fingerlings to allow acquisition of sound estimates of trout abundance, survival, creel entry, and natural recruitment in Spada Lake. At least a portion of the release should be rainbow, and some cutthroat to evaluate their relative contributions to the fishery. Benefits of such a study could be further maximized by marking Tolt River cutthroat stock and assessing their relative performance and longevity several years after their release.

Goal 4. *Manage for optimum species diversity* (within the constraints of the Wild Salmonid Policy).

Rainbow and/or cutthroat are probably native to the upper Sultan River (Description of the Study Area — Fish Species and Brief Life History: Rainbow and Cutthroat). However, eastern brook char are already self–sustaining in several high lakes draining to the lake (Appendix Table 5), and were collected from both Williamson Creek and the reservoir in 1996-97. Brook char are known to be more resistant to *Diphyllobothrium*, either because of natural immunity, or dietary differences. Release of a marked test lot of brook char, coupled with some evaluation of their diet, longevity, growth, parasite load, and creel entry would yield much valuable information.

Coho have been released into Spada Lake in the past (Appendix Table 1), and apparently did not establish a breeding population. Coho are native to the Sultan River drainage. Coho are, at times, less susceptible to lethal infections of *Diphyllobothrium* (Becker and Brunson 1967; Starkey 1970), and contribute well to lowland lake "trout" fisheries (WDFW file data).

Chinook are native to the Sultan River, and can provide high quality fisheries when a suitable fish forage base is available. The potential of this species to thrive in Spada Lake, and its impacts on the "native" trout assemblage should be evaluated. One potential benefit of predation on younger trout would be a reduction in trout planktivory, which may lead to a shift favoring *Daphnia* over *Holopedium*. Increased trout feeding on *Daphnia* would improve trout growth and condition, and perhaps reduce feeding on *Epischura*, the current putative intermediate *Diphyllobothrium* host in Spada Lake.

It is important to note that if enhancement occurs with easily–identifiable species (brook char and salmon should be easily distinguishable from the trout, particularly with public signage and brochures), a regulation could be crafted that would allow potentially liberal harvest limits.

Although exotic species introductions are generally ill–advised, our literature review revealed a species association that has tantalizing implications for the current problems in Spada Lake. Lack of food resources seems to be a severe problem for trout in the reservoir. Whether this situation can be ameliorated by brown bullhead control is currently unknown, and further research is required to find out. However, zooplankton abundance in 1997 was at or above average densities for area lakes and reservoirs; the problem is 75 to 90 percent of it is inedible *Holopedium*. Much of the reservoir's nutrient input is presumed to be either lost to the sediments directly, or routed through inedible species such as *Holopedium* and tiny oligochaetes that are not food for trout. It would presumably be highly beneficial if more of these nutrients could be redirected to trout (or other gamefish) production.

Mysids (*Mysis relicta,* or potentially *Neomysis mercedis*) have been introduced into lakes and reservoirs to provide an intermediate invertebrate link between zooplankton or benthic detritus and fish. The problems with these introductions are well–recognized (Nesler and Bergersen 1991). However, in some cases mysids have focused considerable predation on *Holopedium*, nearly eliminating that species in one Swedish lake, and decreasing *H. gibberum* abundance in another. The abundance of the dominant cladoceran, *Daphnia longispina*, did not change in one of the lakes (Kinsten and Olsén 1981). General reviews of mysid introductions show an increase in the number, growth, and quality of benthic fish, whereas the pelagic fish decrease in number (Fürst *et al.* 1986). *Mysis* introduction has been beneficial for brown trout, lake trout, and burbot in particular (Lasenby et al. 1986). These authors note that "In impounded lakes where food is generally low for fish during the winter, *Mysis* has become an important item in the fish diet."

The objective would be to either redirect nutrients via *Mysis* to trout directly, or provide an invertebrate forage item for one or more new fish species that would utilize the reservoir's benthic detritus foodbase. Trout in Spada are primarily littoral feeders of allochthonous terrestrial insect input. It's unlikely that they would prey on *Mysis* directly. Most salmonids rarely encounter mysids during their active daytime feeding periods when *M. relicta* is in deep water (Martinez and Bergersen 1989). However, a number of authors have reported that *M.*

relicta is an important food of lake trout (*op. cit.*). Lake trout are currently long–established in several lakes in the vicinity of Spada Lake (Isabel, Wallace).

Mysids evolved in sympatry with a number of fish species that are either facultative or obligate profundal benthivores, such as slimy or deepwater sculpin, arctic char, and lake whitefish. Splake (the sterile hybrid of lake trout and brook trout) are reported to feed heavily on mysids (Martinez and Bergersen 1989). While it's possible that mysid introduction would eliminate daphnids as a food resource for the trout, and possibly cause additional consumption of copepods, thus aggravating cestode infection levels (Hammar *et al.* 1983), they may provide a food resource capable of supporting a new, or additional recreational harvest fishery resource in an otherwise sterile reservoir.

There are enough cases where mysid introductions have proved to be beneficial to warrant a very careful literature review to explore their potential for redirection of much (or most?) of Spada's nutrients into fish that would provide some harvest opportunity. The review procedures outlined by Li and Moyle (1981) should be followed explicitly.

The potential for entrainment of any exotic fish species into Lake Chaplain must be considered (it's a given that mysids would end up there).

Recommendations:

Release a marked group of eastern brook char and/or coho into Spada, and evaluate in a manner similar to that of rainbow and/or cutthroat (above). (It may be necessary to delay such a test until a higher–priority test of marked trout is completed.)

Conduct a literature review to assess the potential benefits and impacts of stocking chinook in Spada Lake. Evaluate that species' potential for providing "trophy"–sized fish that can be caught with the types of gear and craft used on the reservoir.

Conduct a literature review, and inter–state consultation to evaluate the pros and cons of introducing one or more new benthic fish species along with *Mysis relicta* to provide a new gamefish harvest opportunity in Spada Lake.

Objective 1. *Maintain consistent presence of all age classes.*

Trout of Age 5 were completely absent from our extensive sample, and only one fish of Age 6+ was taken. Annual mortality was estimated at over 45 percent. To help assure that trout survive beyond Age 3, angling mortality and losses to *Diphyllobothrium* must be addressed. Cutthroat in Spada Lake ate less zooplankton, exhibited slightly lower *Diphyllobothrium* infection rates, and survived in greater numbers to Age 4 and older.

Recommendations:

Revise the minimum size restriction to a maximum size to protect older trout from angling mortality. Retain the selective fishery regulation to allow effective catch–and–release of older fish. A 12" maximum size is easy to remember, easy to measure in the field, and will protect all trout Age 5 and older, as well as faster–growing Age 4 fish.

If necessary, supplement the current Spada Lake cutthroat stock with Tolt Reservoir cutthroat. That stock is known to grow faster, and survive to older age and greater size. If years of fishing pressure on the Spada stock has removed faster–growing individuals, it's possible that some of that genetic loss may be recovered by supplementing with the *unfished* Tolt Reservoir stock.

Objective 2. *Prevent long term reduction in average fish length at age, or growth rate.*

Unfortunately, both have occurred with Spada Lake rainbow and cutthroat. A determination of the relative effects of reservoir aging and diminished food supply versus excessive angling pressure on faster–growing fish was beyond the scope of our study. The former factors are probably much more important than overfishing.

It's possible that excessive numbers of younger aged trout relative to food resources may be responsible for the observed growth rate reductions, but the largest reductions occurred with the older trout age classes. Our larger trout population estimate, if accurate, indicates trout densities are actually quite low. Our diet study failed to show important dietary differences between the various trout species or age groups. Since the older–aged trout were in far lower numbers than Ages 1 to 3, we assume that the effects of competition for food would be most apparent in the younger age groups. In any case, a regulation change that allows some harvest of younger trout may ameliorate food competition to some degree.

Stocking of hatchery trout, or test introductions of other species will likely increase competition for available food. The benefits of obtaining reliable estimates of the trout population and natural recruitment outweigh the short–term impacts on trout growth. This impact may be mitigated to some degree if the introduction is mated with a regulation change that allows harvest of younger trout. The best option would be a short–term regulation that allows unlimited harvest of all marked trout (mindful of the sampling bias that would create in the sport fishery).

Reservoir aging and a diminished nutrient supply are largely unavoidable in an undeveloped watershed. Spada has probably stabilized at an oligotrophic, or ultraoligotrophic status, but this should be verified by more detailed assessment of primary production. The potential benefits of fertilization are well documented (Budy *et al.* 1998 + 63 references). Development of a larger cladoceran biomass through fertilization, perhaps coupled with a reduction in overall planktivore abundance, may lead to increased utilization of *Daphnia* by trout, rather than *Epischura* (or other copepods), increase trout growth rates and condition, and reduce cestode parasite loadings.

The effect of competition from brown bullheads on trout growth is unknown, but is probably significant. Years of population building by bullheads concurrent with a gradual decline in reservoir productivity may explain much of the reduction in trout growth rate and condition. The actual abundance of bullheads and dietary overlap with trout must be determined to fully evaluate this relationship.

There is currently little or no angler interest in fishing for brown bullheads in the reservoir. The current bait ban prevents effective fishing for this species. Unfortunately, designing a regulation that optimizes trout management (release of older fish) requires a bait ban. This conflict poses a fishery management and enforcement challenge. Whether sufficient angler interest could be generated with publicity to make an appreciable reduction in bullhead numbers is problematic, but a sound bullhead population estimate would help greatly in making this decision. We believe some form of set–gear bullhead control program would be far more effective than relying on sport harvest, if further study shows that bullhead numbers and competition are suppressing trout growth.

The level of bullhead population control is impossible to project at present, and depends on the population's overall abundance, age structure, dietary overlap with trout, and competition for critical food resources. We are presuming that competition and dietary overlap exists based on the literature for this species, and high net catches infer at least locally high population densities.

Recommendations:

Obtain reliable population estimates of both brown bullheads and trout to:

1) evaluate the effects of competition for available food;
2) enable estimation of the cost of a bullhead population reduction or control program; and
3) permit modeling of reservoir ecosystem function and fishery dynamics.

Conduct pilot bullhead trapping using baited hoop nets and commercial shrimp pots at various locations around the reservoir. If initial results look promising, use this gear test to perform a mark-recapture population estimate as was done by Imamura (1975).

Conduct a detailed diet study of trout and bullheads in the reservoir, with a focus on the inlet arms. Evaluate the merits of a bullhead control program on the basis of quantifiable shifts in available food resource partitioning from bullheads to trout (or other game fish).

Revise the fishery regulations to allow harvest of some younger trout age classes. Monitor trout growth rates and condition in ensuing years.

Perform a literature review, and consult with experts in other state/s or province/s on the potential effectiveness and feasibility of fertilizing the reservoir to enhance primary productivity and edible forms of the zooplankton community.

Objective 3. *Prevent long term reduction in trout relative condition or mean age at maturity.*

Again, both have declined, particularly the former. The above discussion for Objective 2 is applicable to this objective as well.

Objective 4. *Provide an average catch rate of at least 1.0 fish/hour for trout of any size.*

Catch rates have held nearly constant for the past ten years (while the harvest rate has dropped). Unfortunately, CPUE has averaged 0.57, about one half of the target rate. Stability in CPUE implies that recruitment has been fairly constant, but our gillnet CPUE and age data suggest that recruitment may be low. Our population estimate (10,162) represents a very light density of 5.4 trout/acre at full pool. If this estimate is accurate, it would easily explain angler difficulty in reaching 1.0 fish/hour. A test release of marked hatchery fish would not only enable estimates of trout recruitment and abundance, it would quickly reveal whether enhancement would boost the catch rate.

Reliable estimates of the trout population and recruitment are essential to interpret catch rates, and make decisions as to those management actions that would increase angler CPUE.

Recommendation:

Perform the field studies necessary to obtain reliable estimates of trout abundance in the reservoir, and recruitment from the tributaries. A mark-recapture study is an integral first step, and may be all that is necessary when combined with follow–up sampling in the lake and sport fishery.

Objective 5. *Provide a harvest rate of 0.5 fish/trip for trout 12" or larger.*

When the principal author set this objective in 1995 (Pfeifer 1995), we were ignorant of current trout growth rate and age structure conditions. At present regular attainment of this objective is nearly impossible (every other party/outing yielding at least one trout 12" or larger). The probable cause/s of this condition include overharvest of longer–lived stocks, and possible over–protection of younger fish relative to food resources. Stockpiling of younger trout (assuming our population estimate is incorrect) may have exacerbated excessive planktivory, resulting in a poor percentage of edible plankton forms.

We don't know if survival can be improved to the point where the abundance of trout >12" can be appreciably increased. An essential first step is revision of the regulations to protect these larger, older fish. If recruitment is adequate, and survival (of both hooking mortality and parasitism) is sufficiently high, a very limited harvest of trout ≥12" might be feasible in the future.

This objective was intended to provide opportunity for higher fishery quality on wild trout in a beautiful mountainous setting, but is unrealistic under current conditions. Some level of harvest is essential to satisfy angler desires, and we still wish to provide the opportunity to catch (and release) some larger trout in Spada Lake, therefore this objective should be revised to: "Provide a catch rate of at least 1.0 trout ≥12", and a harvest rate of at least 2.0 trout per trip."

Recommendation:

Revise the fishery regulations to protect all trout 12" or larger, while allowing some harvest of smaller, younger fish. Monitor the results of the regulation change intensively for at least one year, and at a reduced level into the future.

If angler effort reaches 3225 trips/year, critically evaluate the relationship between harvest and recruitment (trout abundance). If effort is likely to increase beyond this level, re–evaluate the feasibility of this objective.

Objective 6. *Regulate the fishery for a maximum yield of 1.15 kg/ha/yr.*

Current harvest levels are far below this ceiling. If angler effort increases appreciably, monitoring and re–evaluation will be necessary to guard against overfishing. However, there is considerable uncertainty as to the actual potential yield of this reservoir. This yield ceiling is based on a generalized mathematical model. It is very useful as a guideline until better measures of Spada's primary and secondary production are obtained. Localized reservoir ecosystem modeling is the ideal approach to management of this fishery if resources are available to do so (Ostrofsky and Duthie 1978; Serchuk *et al.* 1980; Taylor 1981; Duthie and Ostrofsky 1982; Beamesderfer 1988; Swartzman and Beauchamp 1990; Brandt and Hartman 1993; Hansen *et al.* 1993; Cuenco 1994).

Until resources are available to do a more in–depth analysis, the primary indicators to be monitored are trout abundance, recruitment (and/or escapement), age, growth, and condition, as well as harvest levels. It may be necessary, for long–term management, to develop an inexpensive method of estimating trout abundance in the reservoir rather than periodic mark-recapture estimates. However, a one–time mark-recapture procedure, if mated with practicable long–term sampling methods (hydroacoustics or set nets), may reveal strong correlations that will enable routine sampling using one (or both) of the gear methods, rather than repeated marked fish introductions.

Objective 7. *Increase the "quality" aspects of the fishery by assuring maintenance of some older age classes of trout (Age 4 or older).*

Steps recommended for earlier objectives, particularly the regulation change to protect trout ≥12", will address this need.

Objective 8. *Maintain fishery attractiveness such that annual angler use is at least 2.75 trips/acre (ca. 5150 trips/yr).*

Again, this objective was set prior to our field work in 1996-97. The target of 2.75 trips/acre was not entirely arbitrary, but was based on the senior author's experience with lowland lake management in the greater Seattle-Everett area. Also, effort levels on Spada Lake between 1985 and 1989 averaged 4.1 trips/acre. The certainty of taking home some trout undoubtedly was a major reason use levels were higher prior to 1987. After imposition of the 12" minimum size, and perhaps due to removal of trout that may have been more resistant to *Diphyllobothrium*, harvest opportunity dropped to near zero for most of the earlier users. This effort target was an attempt to return to something approaching those earlier levels.

It now appears that high effort levels will conflict to some degree with a harvest objective of 2.0 trout/trip. A first–pass estimate of the number of trips the trout population would support, *based on the theoretical yield ceiling*, is 3225. Clearly, we need a much more reliable estimate of the trout population and annual recruitment. If the fishery is to be maintained strictly on the basis of natural production, the harvest objective may need to be revised, depending on angler effort levels.

Mitigation of Stage II Impacts

As mentioned in Background — Project History and Mitigation Terms ("Stage II"), current mitigation terms prescribe biological studies (this report), an additional final creel survey, and regulation of the number, size, and species of fish stocked, if supplementation is deemed necessary. The practical intent of past negotiations was to assure that fishery–based recreational opportunity was not appreciably reduced in the upper Sultan River basin as a result of the raising of Culmback Dam. A theoretical model indicates reservoir enlargement increased potential fishery yield by 76 percent (and the surface area itself was increased 243 percent, potentially benefitting boaters and appreciative wildlife viewers to some degree). However, recreational fishing on the reservoir has declined 85 percent just since 1985, and is now at a level even lower than that documented during Stage I. It is clear that the "impacts" of Stage II have not been mitigated if one uses recreational use levels alone as a yardstick.

However, the situation is not nearly as simple as the number of anglers seen fishing on the reservoir.

In our 1995 angler survey (Pfeifer 1996b), the most frequent response to the number of times per year anglers visited the lake was once (it was their first visit, or they only fish it once per year). A separate question presented to 260 anglers who had not been previously interviewed revealed that 37 percent of the 1995 users had not fished the reservoir before. These results imply that a large percentage of Spada Lake anglers are "exploring" the fishery; conversely, "regular" anglers may be diminishing in number. Although we did not conduct a rigorous creel survey in 1997, we saw far fewer anglers on the lake than just two years earlier, strongly suggesting a continued diminishment of angler use.

We believe the presence of brown bullheads in the reservoir is a potentially major impact on trout productivity, and thereby, on attainment of reasonable fishery management objectives. The presence of a reservoir on a former free–flowing stream offered a rearing environment that is clearly suitable to this fish species. Thus, successful mitigation of lost stream fishing opportunity due to Stage I and Stage II reservoir development may require some level of bullhead control. Offering *de facto* catch–and–release on small, skinny trout less than 12" in length very clearly is not attractive to the area fishing public. The current regulations and resultant reservoir trout community are not effective mitigation for the former wild trout stream fishery. (Opening the tributaries to catch–and–release fishing would not be mitigation since these streams were available fishery resources prior to Stage I (Appendix Table 2). Allowance of legal harvest in the reservoir, but requiring release of all fish in the tributaries, creates an unmanageable enforcement problem. Finally, if trout fry or fingerling recruitment is currently a problem, any angling mortality or poaching in the tributaries is probably unacceptable.)

Management objectives drafted in 1995 (Pfeifer 1995) were an initial attempt to begin a process of fishery evaluation; this report is the next major step. We find that nearly all of the goals and objectives set in 1995 have not been met (table below). However, most can probably be met to greater or lesser degrees through adaptive management. Some additional research and exploratory enhancement will be required.

Goal or Objective	Attained in 1995-97?
G1	No
G2	Yes
G3	Yes
G4	No
O1	No
O2	No
O3	No
O4	No
O5	(No)
O6	No
O7	No
O8	No

Summary of Management Recommendations

The overall fishery recovery strategy for Spada Lake is as follows: provide some limited harvest opportunity on smaller, younger trout; rebuild older, potentially faster–growing and parasite–resistant trout numbers; reduce grazing pressure on edible forms of zooplankton, principally *Daphnia*; and build numbers of cutthroat relative to rainbow through supplementation with a wild, donor stock. If research indicates it's feasible, begin a pilot program of fertilization and evaluation of its effects on plankton production, and trout diet (and parasitism levels). If research results are favorable, augment the trout population with fully–harvestable fish such as eastern brook char, coho salmon, or other established/native species. If research results are favorable, introduce additional non–native invertebrate and/or fish species to redirect nutrients to harvestable gamefish.

Summary of Additional Research Needs

The principal information gaps are prioritized as follows:

1. Obtain a more accurate estimate of overall trout abundance in the reservoir.

2. Estimate brown bullhead abundance in the reservoir. Evaluate potential control methods.

3. Estimate, by trapping or mark-recapture, annual trout fry or fingerling immigration into the reservoir. Relate the levels observed to escapement or estimated egg deposition to derive a spawner:recruit relationship.

4. Perform detailed dietary analysis on trout and brown bullheads to determine niche overlap, and degree of competition for food resources. Link this study with a more detailed assessment of benthos and surface insect abundance.

5. Evaluate the feasibility of fertilization to enhance primary and secondary productivity. Assess the probability of enhancing trout growth, and reducing mortality due to parasitism by shifts in the species composition of the plankton, and a trout dietary shift.

6. Evaluate the growth, parasitism, survival, and fishery performance of marked eastern brook char and/or coho in Spada Lake.

7. Evaluate the pros and cons of introducing chinook, *Mysis relicta*, or one or more benthic fish species, singly or in combination, to supplement the current low–level trout fishery.

8. Perform genetic stock identification analysis on the trout of Spada Lake (and South Fork Tolt River, if used as a donor stock).

9. Evaluate the survival and reproduction of Tolt River cutthroat stock in Spada Lake.

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Personal Communications

Berger, Peter. 12 January 1998. Water quality specialist, Everett Water Department.

Brunson, Wayne D. Apr-Nov, 1998. Fish pathologist, Wash. Dept. Game/WDFW, 1963-93. (Retired).

Heirman, Bob. 5 January 1998. Member and Officer, Snohomish County Sportsmen's Association, 1950 to date.

Johnston, Jim. January 1998. Area Fishery Biologist, Wash. Dept. Fish & Wildl. District 2, Region Four. Bellingham, WA.

Litt, Arni. 16 January 1998. Research Scientist, University of Washington Department of Zoology. Seattle, WA.

McGuire, Al. 13 April 1998. Area Forester, WA Dept. of Natural Resources, Sedro Woolley, WA.

Miles, Dan. 13 April 1998. Mechanical engineer, Snohomish County PUD No. 1. Everett, WA.

Mundell, Dave. 5 January 1998. Sultan Basin watershed inspector, Everett Water Dept., 1952-1988. (Retired.)

Orrell, Russ. 5 January 1998. Fishery Biologist, Wash. Dept. of Fisheries. (Retired.) Snohomish, WA.

Sneva, John. 24 March 1998. Fish aging specialist, Wash. Dept. Fish & Wildl., Olympia, WA.

Vaugious, Laura. 13 April 1998. GIS specialist, WA Dept. of Natural Resources, Sedro Woolley, WA.