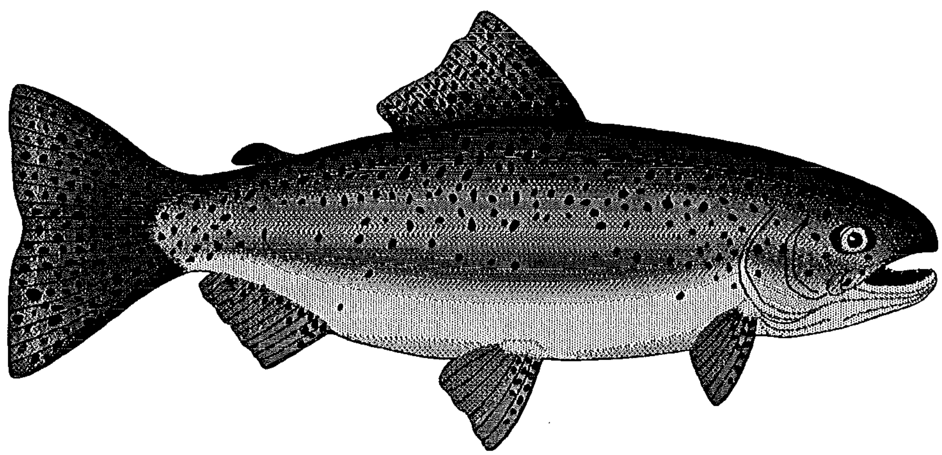
DIAMOND LAKE
FISH MANAGEMENT ISSUES



OREGON DEPARTMENT OF FISH
AND WILDLIFE

MARCH, 1996

DIAMOND LAKE FISH MANAGEMENT ISSUES: TABLE OF CONTENTS

******DRAFT AS OF 28 FEB 96******

DIAMOND LAKE MANAGEMENT AND RESTORATION OVERVIEW

1. Background: Diamond Lake was fishless when first stocked with hatchery rainbow trout in 1910. Since that time it has become one of Oregon's most important and popular trout fisheries.

In 1990, the Oregon Fish and Wildlife Commission adopted a management plan for Diamond Lake which set objectives for its trout fishery: an average of 100,000 angler trips annually, with a harvest of 2.7 fish per angler trip, with fish averaging 12 inches in length. The annual yield of trout should be about 90 pounds per acre. The local expenditure associated with 100,000 angler trips is about 1.78 million dollars annually.

2. Management problem:

<u>**Findings:**</u> The trout fishery has declined in terms of catch, effort, and return on fish stocked (survival). Where the return on fingerlings stocked was ~70% in the 60's and 70's and 80's, it has declined to 20%. The latest creel survey (1994) provided estimates of 54,000 angler- days and fewer than 57,000 trout caught. The decline is due to reduced survival (= increased mortality of stocked fingerlings); fewer fish surviving means fewer fish to be caught. Mortality appears to occur at about the time of stocking.

The fishery has declined to well below management targets. ODFW has received letters from anglers concerned about the fishery and from the commissioners of the five counties surrounding Diamond Lake. County Commissioners offered their cooperation, but underscored the need to seek remedies quickly.

3. Hypotheses for decline and possible restoration strategies:

A. <u>Changes in water quality, manifested as diminished zooplankton or microbenthos production may have led to starvation of fingerling trout or to diminished over-winter survival.</u>

<u>**Findings:**</u> Limnological studies have shown that Diamond Lake is very productive and has large reserves of nutrients in its sediments which are cycled through the water column. There is some evidence of declining zooplankton abundance; one hypothesis is that rooted vegetation is taking up nutrients otherwise available for phytoplankton production which in turn feeds zooplankton eaten by trout. These long term changes in productivity for

growing trout are not understood at present. If zooplankton production is critically affecting trout survival it must be through a dearth of zooplankton at the time of stocking, such that many fish starve before growing to a size at which they can rely on macroinvertebrates or before the lake becomes more productive of zooplankton. Trout stocking has been timed to the period shortly after ice-out in order to maximize the first summer growing period in the lake and to coincide with abundant zooplanktors. If that production is diminished or much later than expected trout growth and survival could suffer.

B. <u>The innate survivability of fingerling Oak Springs rainbow may have diminished, leading to high rate initial mortality after stocking or to reduced over-winter survival.</u>

<u>Findings:</u> Performance of Oak Springs rainbow in the hatchery system does not indicate any systemic problems or conditions which would cause concern for survival after stocking. Fish for Diamond Lake are typically reared at Klamath Hatchery, which has had no new disease or facility problems in the past ten years. The broodstock is concluded to be relatively healthy, with no factors in the hatchery which might limit survival in the wild. Performance after stocking in numerous lakes and reservoirs indicates good survival and growth except under conditions of drawdown due to drought or competition with tui chubs.

A sample of Oak Springs stock will be held in netpens after the lake is stocked in 1996 in order to observe actual initial survival of stocked fish.

C. Rainbow trout survival may be declining due to competition for food with tui chubs and golden shiners.

<u>Findings:</u> Increasing tui chub abundance correlates with declining trout growth and survival prior to the chemical treatment of Diamond Lake in 1954; after treatment trout productivity rebounded and stayed high for 35 years. Chubs clearly were a causative agent for the decline of trout in the 1940s and 1950s, presumably through the mechanism of effective competition for available food (very large numbers of reproducing competitors competing with stocked trout). Golden shiners have been present since 1965 but have remained at low levels. Tui chubs have been present in Diamond Lake for at least five years, but only in substantial numbers in 1995. If chubs are out competing trout for zooplankton and macrobenthos to the point of diminished trout survival, growth and condition of trout should also decline; they have not. If chubs are competing for zooplankton to the extent of causing initial losses of trout, the period of constraint must only be near the time of stocking. The observations suggest that even though the current decline may not be the result of chubs alone, the time is near when chubs will be the decisive factor in lake management

The fishery has declined to unacceptable levels. We reviewed the available data with a team of scientists from ODFW, the US Forest Service, and Oregon State University in order to objectively assess causal relationships and possible remedies. The team concluded that trout mortality occurs around the time of stocking, that survival has been declining since the late 1980s (prior to discovery of tui chubs), and that the tui chub population is rapidly increasing. Neither zooplankton availability nor survivability of the hatchery stock could be ruled out as contributing factors. However, the overriding consideration is the prospect of uncontrolled growth of chub abundance. Previous experience at Diamond Lake and observations of many other lake and reservoir trout fisheries indicates strongly that a crash in the Diamond Lake fishery which is clearly caused by tui chubs is inevitable. Likewise, chemical treatment is inevitable if the fishery is to be restored to meet existing management objectives.

D. Survival may be declining due to some combination of the preceding factors and perhaps other unidentified contributors.

Findings: The possible causes of fishery decline currently identified are not mutually exclusive. There is a strong likelihood that all have or are playing a part in the Diamond Lake fishery. Another possible contributor might be predation by cormorants, but that source alone does not explain the extent of decline which has been observed.

4. Restoration strategies:

Only treatment of Diamond Lake with rotenone to eradicate the naturally producing population of tui chubs will provide a return to the accustomed fishery. Management for objectives adopted in 1990 by the Oregon Fish and Wildlife Commission has been quite popular with the public and we assume that is still the public and Commission's desired management. Treatment will be very expensive, will require a NEPA review, and will raise numerous issues of ancillary impacts.

Diamond Lake management is at a crossroads. Approaches other than treatment are possible, but will result in very different fisheries. Doing nothing other than the strategies listed below as "interim" is an option as is management for a low catch-rate "trophy" fishery. The interim strategies will not turn around a fishery declining because of tui chubs. Establishment of a "trophy" fishery would require a different trout stock. All of the options named pose tough public questions. Treatment, loss of the fishery through no action, or introduction of new trout stocks will raise controversy. We are prepared to discuss these with the public in the context of restoration of the Diamond Lake fishery based on current objectives.

Long term restoration:

Costs

Powdered rotenone sufficient to treat the lake will cost about $355,000 assuming that the lake is drawn down eight feet to reduce its volume and contain the toxic water. Restoration of the canal used in the 1954 treatment has been estimated by USFS engineers to cost about $350,000. Equipment, personnel, and associated costs of rotenone application could be another $100,000. Staff time to complete environmental review documents and plan the treatment are not estimated but would be very substantial.

Issues and problems

Several issues will arise from any proposal to kill the fish in Diamond Lake with rotenone. ODFW has encountered and resolved similar issues in other treatment projects.

- introduction of chemicals into aquatic environments: there is a heightened public concern about the use of chemicals, independent of the specific effects
- wildlife issues, especially the effects on nesting bald eagles, ospreys, and goldeneyes; consultation with the USFWS will seek avoidance or mitigation of impacts to eagles and other birds; the public will likely raise concerns for fish-eating mammals, reptiles and amphibians, and benthic organisms.
- downstream and in-lake effects of drawdown of the lake
- reduction of fishing the summer preceding treatment; loss of fishing after treatment; reduced opportunity the summer after treatment; all present additional economic costs to businesses associated with the lake as well.
- disposition of fish killed at treatment
- cost: a very large investment of public funds from outside the Department will be needed
- time for NEPA review process and to plan treatment

Approval process

Chemical treatment of Diamond Lake will require a review as described by the National Environmental Policy Act (NEPA) which includes an extensive public consideration of alternatives, benefits, and consequences. ODFW has an environmental assessment on file with the USFWS covering the Department's chemical rehabilitation activities and concluding that there is no significant impact from them. However, the scope of issues at Diamond Lake will require a separate document and process. ODFW will likely have the lead responsibility for writing the assessment, with the USFS as the agency administering the NEPA review. Time required to write the review document and carry out the process is uncertain at present but is certain to be more than a year and to pose a substantial workload to ODFW.

Interim strategies: Several strategies have been examined for use in the near-term while approval is being sought for chemical rehabilitation and the treatment project planned. These are management actions intended to mitigate the decline of fingerling trout survival. All have costs and benefits; none is capable of solving the current management problem or restoring the character of fishery which is expected at Diamond Lake. A synopsis follows:

- use larger fingerling rainbow trout to avoid early competition with tui chubs
- supplement with large releases of catchable rainbow trout
- continue current management: stock 400,000 Oak Springs fingerlings at 50/lb

Alternative strategies: if chemical treatment is not available or is greatly delayed, these actions may be useful in maintaining a fishery. These actions will not be taken in 1996, but are being reviewed for their feasibility. The adopted management objectives would not be met, and new objectives reflecting a lower catch rate, but the presence of "trophy" trout would need to be adopted if the lake is not to be treated. A different angling clientele willing to expend far more hours per fish would likely be attracted to Diamond Lake, and many of those using the lake today would fish elsewhere instead.

- introduce different strains of rainbow expected to persist in competition with tui chubs and to feed on chubs, subsequently reaching large size
- introduce new species of trout expected to persist, feed on chubs, reach large size
- annually use partial chemical treatments or netting to remove chubs

BACKGROUND

Description of Diamond Lake

Diamond Lake is part of the Umpqua River basin system in southwestern Oregon. A natural lake located at the 5182 foot elevation in the Cascade Mountain range, it is drained by Lake Creek, which flows northward to join the North Umpqua River at Lemolo Reservoir (see Figure 1, page 7). It is part of the Umpqua National Forest in Douglas County, and lies just north of Crater Lake National Park.

The lake holds 78,000 acre feet of water in normal years, with a surface area of 2,982 acres; it is 3.5 miles long, north to south, and 1.5 miles wide. Maximum depth is 52 feet, but most of the lake is less than 20 feet deep. The basin area that drains into the lake is approximately 55 square miles of surrounding land.

Land Use

The lake is managed by the Forest Service for primarily recreational use. Private cabins are located along the western edge of the lake, and a commercial lodge, the Diamond Lake resort, is located at the northeastern end of the lake. There are three large Forest Service campgrounds and five boat ramps. Summer recreation at the lake includes swimming, boating, camping, and fishing. In 1995 Diamond Lake had almost 800,000 visitor-days, according to Forest Service personnel (Craig Burns, personal communication 1995).

Surrounding forest land is managed primarily for timber production and recreation.

Water Use

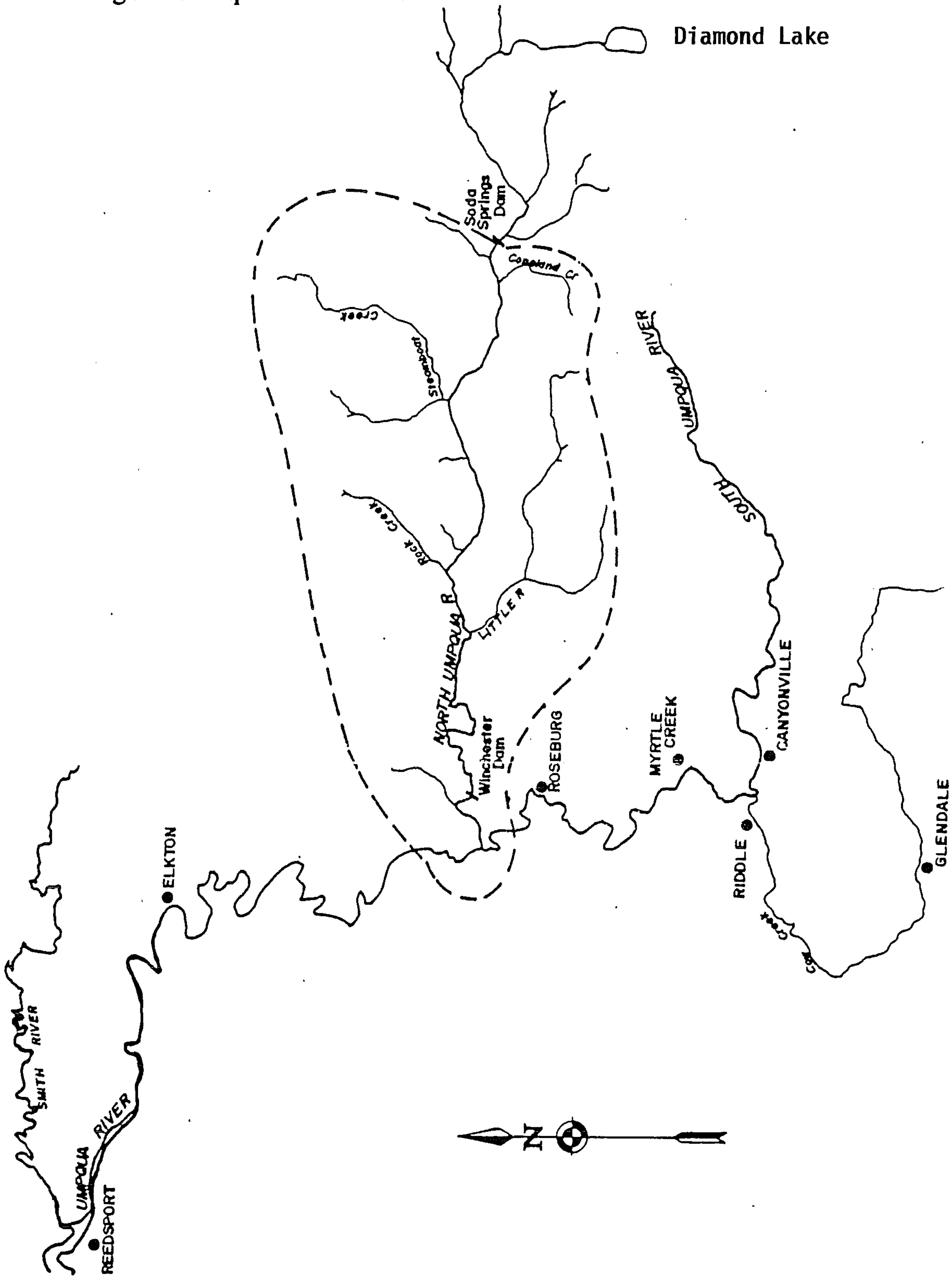
None of the water in Diamond Lake or Lemolo Reservoir is used as a domestic drinking supply source. Cabins in the vicinity of the lake, and the campgrounds, are supplied with drinking water from wells.

Description of Fishery

History of Fish Management

Diamond Lake is believed to be fishless historically, not because the lake is incapable of natural fish production but because numerous steep waterfalls downstream would have blocked the migration of fish from the lower areas of the basin. No record of fish at Diamond Lake prior to stocking with trout by the Department has been found. Rainbow

Figure 1: Map of Diamond Lake



trout of Spencer Creek (Klamath basin) origin were first put into Diamond Lake in 1910, and they were so successful that an egg-taking station was established in 1919 by the Oregon Fish Commission. This station operated for 33 years, utilizing rainbow trout eggs to restock the lake and as a supply source for other hatcheries; in one year approximately 17 million eggs were taken. At one time in the 1920's it was the largest egg-taking station in the world. Rainbow trout were stocked into Diamond Lake at increasing levels up until 1946, when the numbers of fish began to be reduced (see Table 1: Diamond Lake Stocking 1910 through 1954).

During this time also tui chub (Gila bicolor), a minnow native to the Klamath basin, were introduced into the lake, probably as bait fish. Over the next few years, the population of chub increased and the trout fisheries began to decline.

Beginning in 1946, efforts to control the tui chub population included seining and partial chemical treatment in the shallow areas of the lake where they were observed to be spawning. These methods did eliminate over 68 million chubs between 1946 and 1950 (Dimick, 1954), but the tui chub continued to flourish, and the rainbow trout populations continued to decline.

In 1954 the entire lake was treated with rotenone to eliminate all fishes. The biologist coordinating the operation, John Dimick, estimated that 32 million tui chub were killed, or around 400 tons of fish.

After a year, 1955, in which the fishery at the lake was closed, a spring-spawning strain of rainbow trout, the "Kamloops" stock (British Columbia, Canada) were introduced into the lake. At the time it was presumed that the Kamloops rainbow trout, although not native to Oregon, were a "pure" strain: they had not been genetically mixed with other rainbow trout stocks and would perform better than stocks used previously. Stocking of Kamloops rainbow was discontinued after 1961 due to their poor body condition in the spring when the season opened and due to their relatively low fry to adult survival. From 1962 through 1969 a mixed stock rainbow trout was used: these trout were of Willamette River, Roaring River, and Oak Springs origin. These were fall-spawning fish stocked as fingerlings, and had an exceptional survival rate of around 70% to the creel.

Recent Fish Management at Diamond Lake

The current management plan for Diamond Lake is based primarily on the fishery results of fingerling stocking from 1963-1978, and the monitoring of lake productivity through benthic organism surveys and fish condition factors. The ODFW Commission adopted a formal management plan in 1990 that directs the Department to provide for a basic yield of rainbow trout from hatchery fish only. The specific objectives include providing an average of 100,000 angler trips with a catch rate of 0.5 fish per angler-hour

Table 1

DIAMOND LAKE STOCKING
1910 THROUGH 1954

1910 - 1938	1.0 MILLION FRY
1938 - 1945	2.0 MILLION FRY
1946	4.0 MILLION FRY
1947	3.3 MILLION FRY
1948	2.0 MILLION FRY
1949	NONE
1950	49,000 LEGALS
1951	47,000 LEGALS
1952	49,000 LEGALS
1953	32,000 LEGALS
1954	NONE

or about 2.7 fish per angler trip. The total catch goal of 270,000 rainbows should average 12 inches and yield about 90 pounds of trout per acre annually. The fish condition index (K-factor) for 8-10" fish in October should range between 1.3 and 1.4, based on the normal fingerling releases of 400,000 fish at 50/lb in June.

Current monitoring activities indicate the present status of the Diamond Lake fishery is well below management goals. The significant increase of the tui chub population during relatively the same time period suggests this population is again the primary cause of the trout fishery decline.

The current profile of the Diamond Lake fishery is that of greatly reduced trout abundance and greatly increased numbers of chubs. This association was also observed in the 1940's and 1950's prior to treatment of the lake.

Economic Value of Fishery

Economic Impact of Changes in the Fishery

It is likely that the recent decline in angler use in the Diamond Lake trout fishery has had an adverse economic impact on the surrounding economy. Although we have not conducted an economic survey of Diamond Lake anglers specifically, estimates from the Oregon Angler Survey provide some perspective. Anglers coming from outside the area to fish for trout in lakes and reservoirs of the southwest angler zone spent about \$17.82 per angler day in the area, based on average destination and half of enroute expenditures. Additional expenditures made outside the area are not included in this estimate. The in-zone personal income associated with this \$17.82 expenditure was an estimated \$13.57. The expenditure figure is an average over anglers of all descriptions, including those who camped, those who stayed in motels and lodges, and those who took day trips.

Assuming the decline in the fishery has led to reductions in the level of overall recreational use comparable to the decrease in angler days, we can project the impact of the fishery's recent decline, and suggest the potential economic impact of restoring the fishery to previous levels. The level of angler use has recently declined to a level of about 50,000 angler days annually, compared to a goal of 100,000 angler days. An additional 50,000 days at the average expenditure level of \$17.82 amounts to an annual increase in expenditures of about \$891,000 in the area. Over a twenty year period, the restoration of the fishery could increase expenditures in the area by about \$17.8 million, if, in fact, recreationists' visits to the Diamond Lake area increases along with the projected increase in angler days. So the effect on local business activity could be significant if our assumption about the relationship between tourism and angling is reasonable.

The annual increase in total personal income in the southwest zone associated with the increase in trips would be about \$678,500. Of course, this income impact would be spread over the southwest zone, which is somewhat broader than the local area around Diamond Lake.

Another measure of the value of improved fishing is the value of the increased or improved activity to the angler. Because recreational fishing is a non-market good, economists have devised indirect methods to estimate angler net willingness to pay above actual participation costs. Estimates for the value of the trout fishing experience range from between $20 and $50 per day depending on the location and type of fishing. These estimates suggest that, in addition to the positive effect on business activity, anglers themselves would receive economic (but nonfinancial) gains if the fishery were improved.

Finally, a recent analysis suggests the marginal value to anglers per additional trout caught per year is about $1.38 per fish. Associated with the target for increasing angler use is an increase in annual catch at Diamond Lake from about 57,000 fish to 270,000 fish. Based on the estimated marginal value, this quality improvement would be worth about $294,000 per year, in terms of anglers' additional willingness to pay.

Lake productivity, catch rates, and hatchery program

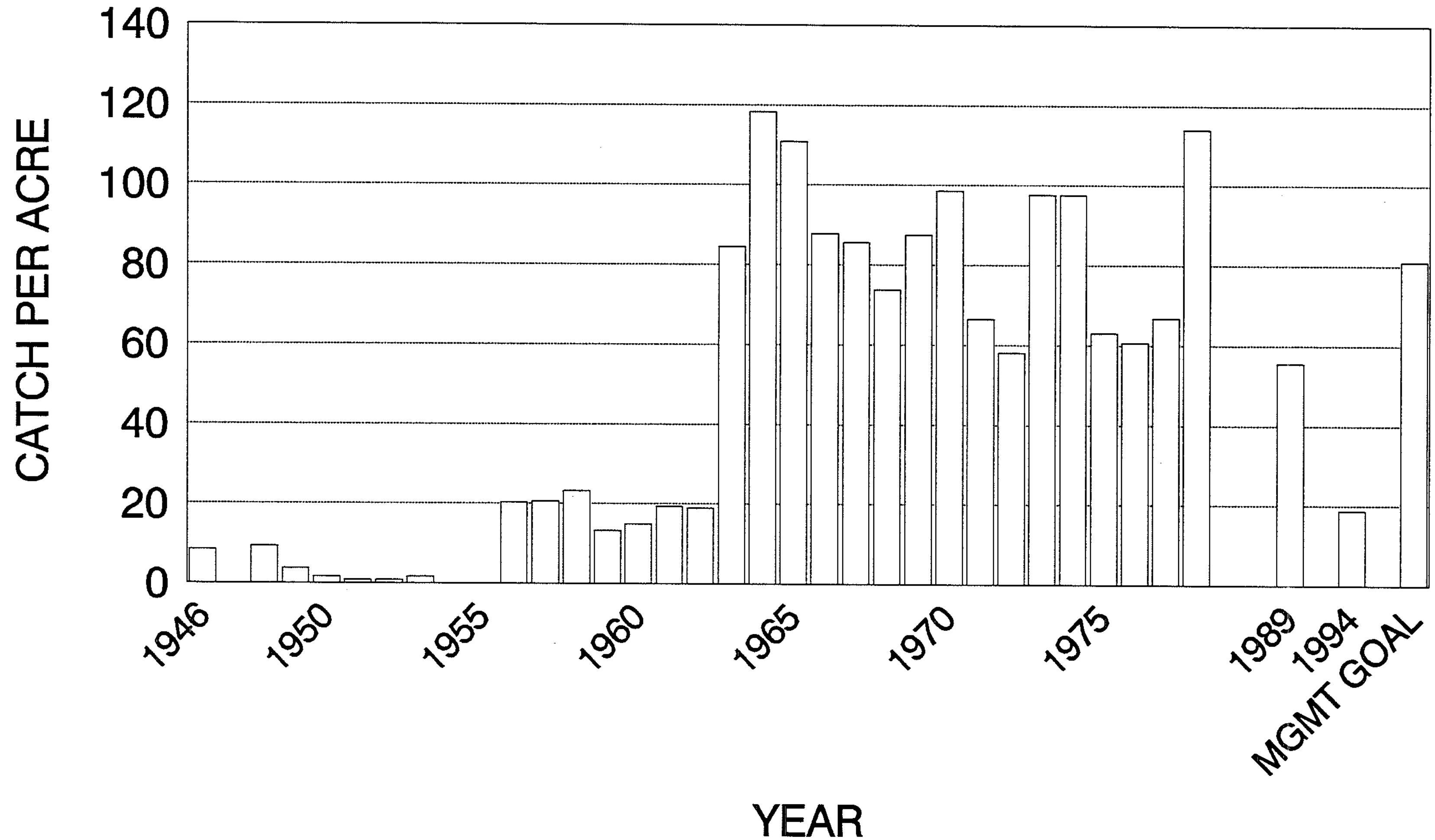
Diamond Lake has historically been a very productive lake in terms of growth rate and overall pounds of fish harvested annually (Table 2). In a typical year, Oak Springs rainbow fingerlings are released in early June at 50 fish/pound or about 4 inches in length. These fish enter the fishery in August and contribute to nearly half of the catch in the fall months as 8-10 inch fish. The following season yearling fish average 12-14 inches, weigh nearly a pound, and provide anglers an excellent opportunity to harvest several thousand nice rainbow trout. About 10 percent of the fingerlings normally survive the first year's fishing and natural mortality as 2-year olds and grow to an average of 14-16 inches during the second summer in the lake. Some fish reach 20 inches or over in length in 3 or 4 years, but the high annual harvest rates, and overall natural mortality of this domestic rainbow stock limit the numbers of available trophy-sized fish.

The overall survival rates of the annual fingerling releases in the 1960's and 1970's were very high based on the comparison of numbers of fish stocked and the catch levels the following years for that age-group. The rate of return to the fishery from hatchery releases averaged 73 %, with a range of 55 to 90 per cent. Since over 70 percent of the fish are harvested as yearlings, this indicates that the initial survival rates of the fingerlings must be very high to achieve the overall goal of three fish harvested for every four fingerlings stocked. There is a small portion of the fish population from natural spawning production in the lake or tributaries, but this number is insignificant to the total harvest levels.

The hatchery program with Oak Springs domestic rainbow has provided an annual fishery yield of 61 to 118 pounds per surface acre, with an average of 86 pounds/acre since 1963. Annual sampling of the lake's benthic food production indicated the stocking rate of 400,000 fish was the maximum level for a sustained fishery. Higher number of fish releases reduced the high productivity of the lake, and lowered the overall growth and

Table 2: DIAMOND LAKE FISH PRODUCTION

CATCH (LBS PER ACRE)



survival rates of the hatchery fish. A condition factor index based on the length and weight of fish sampled in October has been used to monitor the lake's productivity after the benthic sampling program was discontinued in 1980.

Decline in fishery:

Since the late 1980s, the trout fishery at Diamond Lake has declined in numbers of anglers, total fish caught, catch rates, and overall return on hatchery fingerling releases. Statistical creel surveys were completed in only two years since 1978. The catch and effort estimates from 1989 indicated that the fishery had declined below average levels, but over 80,000 anglers still visited Diamond Lake. The trout harvest level was about 170,000 fish or about 70% of the long-term average. The catch rate was near the 0.5 fish/angler hour average and anglers were still harvesting slightly over 2 trout per trip.

Another creel survey was completed in 1994, showing the total catch and effort numbers to be at the lowest levels since 1962. The survey estimated there were only 54,000 anglers and the total trout harvest was less than 57,000. The catch rate had dropped to less than 0.3 fish per hour and the harvest was down to only 1 trout per angler trip. The overall productivity of the lake had dropped to only 18 pounds of trout/acre, which was also the lowest figure since the early 1960's. District and volunteer creel information indicated the catch and effort remained very low in 1995.

The hatchery program has been based on Oak Springs domestic rainbow fingerlings since 1962. The return rate of yearlings was only 13% of the total fingerling releases in 1993. This compares to a 60% average rate for previous years. Length frequency for the total catch has not yet significantly changed, which suggests the additional mortality must be occurring during the first few weeks after the hatchery fingerlings are released. Growth rates for the trout that survive to October have been within the expected ranges, but condition factor indexes have been at or below average since 1987. This indicates potential food production in the lake has also declined, as lower releases of fish in past years showed an immediate response of larger fish in the fall. The benthic sampling program was discontinued several years ago, so the data is not available to confirm this information.

Short term, remedial actions taken to reverse decline in fishery:

Due to the apparent decrease of fingerlings survival, additional stocking programs have been initiated in recent years to provide increased numbers of harvestable trout. Between 5,000 and 14,000 legal-sized trout were stocked annually into Diamond Lake since 1992 to supplement the 10-12" trout population. The return rate of these fish has been over 40% to the fishery, but still represents a relatively small number of fish compared to the total harvest of 50-60,000 fish resulting from the 400,000 annual fingerling releases. In addition, in 1992 and 1994, the allocation for fingerling releases was increased by 25,000 to compensate for some of the higher mortality rates. Stocking procedures were also modified to reduce bird predation on disoriented fish shortly after release. Fingerlings were stocked into different areas of the lake to assure all potential food sources were available to the hatchery fish.

An experimental introduction of 12,000 fingerling rainbow trout of Williamson River stock was made in 1995. These trout survive in Klamath Lake in direct competition with tui chub. In Klamath Lake Williamson rainbow trout grow to a large size (fish over 20 pounds are caught annually) feeding primarily on tui chub and other minnows, but may be more difficult to catch with methods typically used by Diamond Lake anglers.

HYPOTHESES FOR TROUT FISHERY DECLINE

Several hypotheses have been offered to account for the observed decline in the trout fishery at Diamond Lake. These include:

1. Rainbow trout survival may be declining due to competition for food with tui chub and golden shiners.

History of Tui Chub in Diamond Lake

Tui chub in Diamond Lake previously caused the collapse of the rainbow trout fishery. A brief history of that decline and subsequent recover will help place the current findings in perspective.

Tui chub (Gila bicolor), a fish native to the Klamath basin, were introduced into the lake, probably as bait fish, sometime during the 1930's. Over the next decade, the population of chub increased and the trout fisheries began to decline. A creel survey in 1947 estimated 37,500 trout, averaging 13.75 inches and nearly 1 1/4 pounds, were harvested by over 26,000 anglers. By the early 1950's, only 6,000 anglers were fishing the lake annually and the annual trout harvest had dropped to less than 6,000 trout. The average trout size diminished to 9.5 inches and slightly over one-half of a pound. The rainbow trout stocking program was increased to 3 million fry in 1946. About 50,000 legal-sized rainbow were stocked annually from 1950-1953, but the return to the fishery averaged less than 15%.

In 1950, a gillnet sampling program was begun to evaluate the composition of fish species in the lake. This experimental gillnet monitoring showed increasingly higher levels of tui chub and a concomitant decrease in rainbow trout (see Table 3: Ratio of Tui Chub to Rainbow Trout, 1950 - 1953 and 1993 - 1995). This led to the obvious conclusion that the expanding tui chub population was responsible for the depressed status of the rainbow trout in the lake.

Table 3: Ratio of Tui Chub to Rainbow Trout

1950 - 1953 and 1993 - 1995

	TUI CHUB*	RAINBOW	RATIO
1950	750	15	1:94
1951	1097	8	1:137
1952	1981	8	1:128
1953	420	0	1:420
1993	6	6	1:1
1994	165	54	1:3
1995	260	12	1:27

* = > 5" IN SIZE

Beginning in 1946, efforts to control the tui chub population included seining and chemical treatment in the shallow areas of the lake where they were observed to be spawning. These methods did eliminate "millions of roach" (Dimick, 1954), but the tui chub continued to flourish, and the rainbow trout continued to decline.

During the 1940's and early 1950's when the tui chub population rapidly increased in the lake, average weight of the trout declined 50% in three years. In an attempt to reduce the competitive advantage of tui chubs in comparison to fingerling trout the fry stocking program was discontinued and only fingerlings or legal-sized fish were released from 1950-53. This action met with little success. Trout caught per acre continued to decline over 90% from an already low level of 9 lb in 1946-48 to only 1 pound in 1951-53. The fishery had declined to catch levels of less than 0.3 trout per hour and 1.0 fish per trip. The lake's benthic food production dropped from nearly 300 lb. per acre in 1946 to 15 lb./acre in 1948. The natural food production available to trout by 1951 was estimated at only 2 pounds per acre. Anglers were primarily catching trout that were stocked only a few weeks earlier as legal-sized fish. Few fingerling trout survived to be harvested.

Tui chub were probably near their maximum production level in the 1950's and had established a large, naturally spawning population in the lake. Benthic organism sampling indicated the chub population was able to utilize most of the available natural food production that rainbow trout fingerlings needed for growth and survival. Any trout management program with tui chub present would have had to be based primarily on a put-and-take fishery, or on a strain of trout which could compete more successfully for the available food sources.

In 1953 the decision was made by the Game Commission to chemically treat the entire lake. An artificial outlet for the lake was constructed in the summer of 1953 to allow drawdown of the lake and prevent treated water from flowing out through Lake Creek before it naturally detoxified. Draining the lake began July 1954, and by September the surface of the lake had subsided 8 feet. The lake was treated with powdered rotenone 21 September 1954. The biologist in charge of the operation, John Dimick, estimated that 32 million tui chub were killed, or about 400 tons of fish.

Post-Treatment Rebound of Trout Fishery

Diamond Lake was stocked in June, 1955, with Kamloops rainbow trout. This stock was non-native to Oregon, but was considered the only pure strain of rainbow trout that could be obtained in large enough numbers to meet hatchery needs. A total of 147,000 4-6" fingerlings and 385,000 fry were obtained from Canada. An additional 245,000 Kamloops rainbow trout fry were released in 1956. By 1958, the Diamond Lake egg take was again several million from fish captured in the lake during late spring. In 1961, the total egg take was 15.5 million eggs and represented over 75% of the trout eggs for the entire state. The actual number of fish released in Diamond Lake was about 1 million fry annually.

In 1962, a different stocking program was tried with new strains of domestic rainbow trout, providing larger-sized fish at release, and stocking fewer fish than previously. Oak Springs rainbow trout fingerlings released in early June have been the only hatchery stocking program for the Diamond Lake fishery since 1970. Other domestic rainbow trout stocks were released in the lake in the 1960's at different sizes and times, but the highest return to the fishery has been from Oak Springs stock. The major difference between the domestic rainbow trout programs tested at Diamond Lake has been size at release. Spring spawning fish such as the Kamloops strain produce a fry-sized fish by June which survives relatively poorly. Fall spawning Oak Springs stock produce a larger fingerling by time of release in Diamond Lake in June which survives well.

The increase in harvestable trout available in the lake from fingerling releases compared to fry releases was immediately apparent during the 1963 fishery when the number of fish harvested increased to 250,000 or 5 times the average catch since treatment. Fishery effort almost tripled to nearly 100,000 angler trips. Yield of trout per acre increased from 20 to over 80 pounds annually, with a high of 118 pounds in 1964. Catch rate sharply increased from 0.27 trout per hour to over 0.6 fish per angler hour, with an average of 0.58 over the next 15 years. The number of fish per angler trip averaged 2.7 for Diamond Lake from 1963-1978, compared to 1.1 fish per trip in 1956-62.

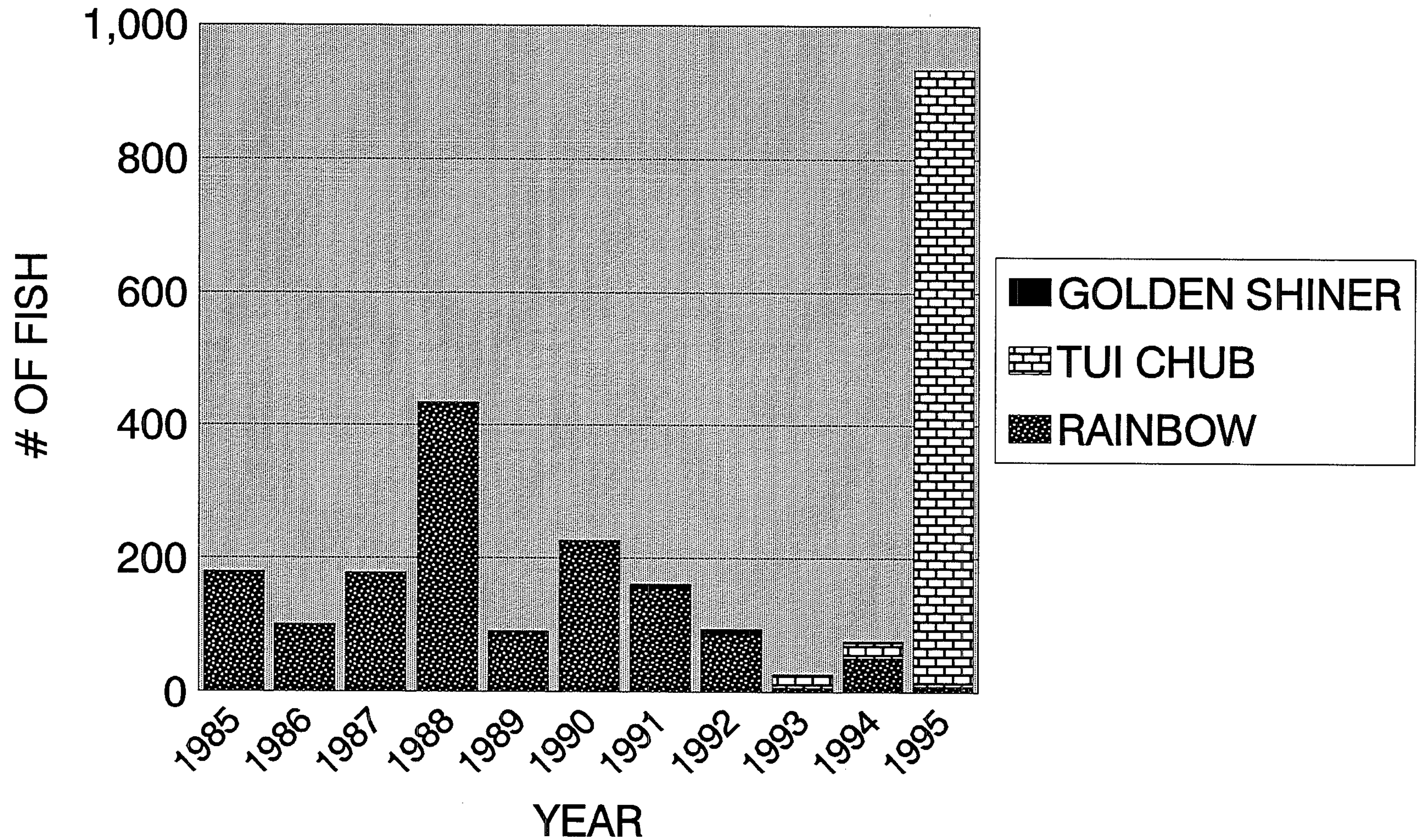
Recurrence of Tui Chub Problem

The present status of the Diamond Lake fishery is well below management goals. During relatively the same time period tui chubs have again become abundant. If tui chubs are not the immediate cause of problems at Diamond Lake at present, they certainly will cause problems in the near future. Tui chub were documented in the lake in 1992 for the first time since the rotenone treatment in 1954. The following table shows the relative population abundance of rainbow trout, tui chub, and golden shiner in Diamond Lake based on the annual overnight set of one trapnet (Table 4). Trout have declined in the past few years with a comparable increase of tui chub. Direct observations of large schools of "minnows" during the summer of 1995 also suggest the tui chub population has increased significantly in the past 2 years.

Tui chubs are assumed to compete with fingerling trout for zooplankton early in the growing season when both species are associated with shallow shoreline areas. If chubs are very abundant or if zooplankton abundance is limited, trout survival will suffer. Larger fingerings are able to consume insects and other large invertebrates and are less affected by zooplankton availability. Both tui chubs and trout feed on those organisms, but trout move offshore to deeper water as the lake warms. So far, it is assumed that tui chub numbers are not high enough to reduce food availability for trout in the deeper waters (hence the observation that surviving trout continue to display expected growth and slightly diminished body condition). As the chub population builds, competition can be expected to reduce survival, growth, and condition of trout as seen in the 1950s.

Table 4: DIAMOND LAKE INDEX TRAPNET RESULTS

1985 THROUGH 1995



Diamond Lake needs to be closely monitored in the next year to better determine the lake's fish population status and evaluate any possible restoration activities. Trout harvest, fish size and condition, and data on survival of hatchery releases should be collected to provide pertinent information. Fishery creel surveys and increased fish population sampling is needed on a regular basis. Additional studies related to hatchery release strategies, lake productivity and wildlife species should also be considered.

The most recent creel survey, conducted in 1994, indicates that the overall fishery has declined to less than 55,000 anglers and 57,000 harvested trout. Survival of the Oak Springs rainbow fingerlings declined from nearly 70% to less than 20%. Trout production has dropped to less than 20 pounds per acre, compared to an average of over 80 pounds annually. This is the lowest return rate and overall trout production ever from the fingerling stocking program. The catch rate of trout by anglers was only 0.29 fish per hour, which is 50% of average. The number of fish caught per angler trip was 1.08 in 1994, compared to 2.03 in 1989 and the long-term average of 2.7 for 1963-78.

The population sampling program was expanded in 1995 to include monthly trapnet sets. The tui chub population has increased sharply, and presently outnumbers the trout population. The ratio of tui chub(>5") to rainbows in the October sampling has increased from 1:1 in 1993 to over 25:1 in 1995.

2. Water quality changes in the lake may be causing a decline in rainbow trout survival.

Limnological studies

Limnological studies reported by Salinas and Larson (1995) conclude that the lake's capacity to produce phytoplankton (and hence, zoopankton) may have diminished over the past 25 years. However, zooplankton and other limnological data have only been sporadically collected and do not offer an answer to two questions raised in the context of trout management issues: is there sufficient zooplankton in early June to support fingerling rainbow at current stocking levels; and, is there reason to believe that long-term potential to produce zooplankton is diminished from that of the 1960s and 1970s.

One rationale for the poor survival of trout stocked as fry in the 1940s and 1950s compared to fingerling releases in the 1960s and 1970s may be that Diamond Lake is historically not highly productive of zooplankton. Fingerling rainbow would be dependent on zooplankton only briefly, moving soon to the lake's large biomass of benthic macroinvertebrates.

Given the equivocal and incomplete data available, importance of zooplankton abundance to the management problem at Diamond Lake cannot be defined. In 1996, a group of fingerling trout from routine releases will be held in netpens to observe their survival and test assumptions regarding fish health and trout/chub interactions for a period immediately following release.

3. The quality of the hatchery stock may have declined over the years, and this may have reduced the survival of rainbow trout stocked in Diamond Lake.

Hatchery and field performance records at various lakes and reservoirs in Southeast, Central and Southwest Oregon were reviewed to determine if any consistent declines in survival had occurred in the past decade.

Hatchery Performance

Lot number 53 rainbows are a mixture of two stocks; eggs obtained from Utah in 1923 (undoubtedly McCloud river egg takes) and sperm from an unknown stock from Tacoma, Washington, in 1971. These fish are fall spawners, which is critical in enabling the hatchery to rear a 50 per pound fingerling for release at Diamond Lake in early summer.

Since 1979, Lot number 53 rainbow have been used to stock Diamond Lake. Size at release has generally varied from 30 per lb. to 100 per lb., with most releases in the 60 per lb. range. Spring release in late May or early June is the preferred time. The majority of fish have been reared at Klamath Hatchery.

Hatchery performance records were reviewed to determine if there was any noticeable declining trends in fecundity and general health of the brood stock, disease history and trends in egg or fry losses in the resultant progeny. In reviewing survival of Oak Springs brood fish used in the Klamath Hatchery (Diamond Lake) program, very little mortality is seen in the one year or two year old brood fish. Most losses are associated with post spawning diseases such as fungus or by physical injury at age 3 or 4.

Generally, spawning dates were consistent over the years from mid-late September through mid-late November. Eggs were sent to Klamath from Oak Springs from spawnings in late September through late October and approximately 1/3 to 1/2 of all eggs taken were transferred, giving Klamath a good cross section of fish available through the late October spawnings. Later egg takes were not sent due to the inability to push these late fish to the desired stocking size at Diamond Lake by May of the following year.

Egg and fry losses at Klamath Hatchery remained fairly constant during the mid-80's and early 90's. There does not appear to be any negative trend, particularly in losses at the egg and fry stage.

An interesting fact is that all hatcheries rearing Oak Springs rainbow do not see a noticeable loss of Lot 53's from ponding until release. Once fish are put into ponds, the survival rate is in the mid 90% range until liberation, even at hatcheries with cold water disease (CWD).

Department pathologists report no new fish diseases at Klamath or Oak Springs hatcheries over the past decade or more. They do report more findings of CWD, but that is probably due to better technology and their ability to detect diseases with more frequent monitoring.

They report finding Cold Water Disease in 1984 at Klamath Hatchery and every year since. Even though CWD was found in the fingerlings, pathologists report the disease was very light if present at all upon release, since fish are treated to eradicate or reduce the number of CWD organisms. At Klamath Hatchery good growth occurs when CWD is not present. Pathologists say by reducing densities of fingerlings in hatchery ponds, you can reduce the incidence of CWD. They also feel those few fish which may have low levels of CWD at liberation would not succumb, due to the small number of disease organisms present, and the large dilution factor of the lake receiving the fish.

The conclusion from the Fish Culture Section is that the broodstock is relatively healthy and that hatchery practices, CWD or other pathogens, were not factors negatively affecting survival after release, at any lakes or reservoirs utilizing Oak Springs rainbow trout.

Field Performance

Survival and condition factor of fingerling Oak Springs rainbow trout during the last decade were reviewed at several Southeast, Central and Southwest Oregon lakes and reservoirs.

At Chickahominy Reservoir in Southeast Oregon, survival and condition of stocked fingerling has been excellent, in the absence of competitor species, during recent high water years. Condition factors ranged from 1.57 in 1993 to 1.68 in 1995.

Samples at nearby Beulah and Malheur reservoirs in 1993 revealed healthy rainbow trout condition factors of 1.31 and 1.33 respectively. Beulah Reservoir contains additional competitive species such as squawfish, coarsescale and bridgelip suckers, but no tui chub.

Thompson Reservoir was most recently chemically treated to eradicate tui chubs in 1988. In 1989, in an abundant water year and in the absence of tui chub, rainbow trout condition factors averaged 1.58. By 1993, again in an abundant water year but with a rebuilding tui chub population, trout condition factors slipped to 1.41. By 1995, with only marginal water levels left at the reservoir in the fall (9% of capacity) and increasing tui chub, Thompson trout conditions again dropped to 1.16.

In Central Oregon many lakes and reservoirs contain illegally introduced tui chubs. At lakes with tui chub, recovery of trout has been successful where complete chemical treatment has been possible. At South Twin Lake in 1986 with abundant tui chub, rainbow trout survival and growth was poor, with condition factors averaging only 1.17. Following chemical treatment in 1987, condition factors rebounded to 1.25 in 1990. Similar to the aforementioned Southeast and Central Oregon reservoirs, Howard Prairie and Hyatt reservoirs in Southwest Oregon are also consistently meeting fishery objectives during recent years when absence of tui chub and adequate water levels allow. However, historically, over populations of tui chub and warmwater fish have severely limited trout production at these locations. During the period 1990 to 1995, in the absence of competitor species, condition factors for Oak Springs rainbow trout exceeded 1.30 at each reservoir. Local biologists now believe that reservoir drawdown is probably the most influential factor affecting yearly variation in trout survival levels in these water bodies.

At nearby Fish Lake, available data strongly suggests that fingerling rainbow are consistently failing to meet fishery objectives because of detrimental interactions with tui chubs. Partial chemical treatment at Fish Lake was last conducted in 1985. Condition factors for trout with low tui chub abundance was 1.25 in 1986. During the period 1990 to 1995 in the presence of expanding tui chub populations, trout condition factors have consistently been poor, averaging 1.15 or less.

In conclusion, Department District Biologists utilizing Oak Springs fingerling rainbow feel these fish still provide viable fisheries in the absence of tui chub and when drought conditions do not otherwise exacerbate survival conditions. In the presence of tui chub, fingerling trout survival and growth consistently decline, with few trout holding over to the next season. During drought conditions, stocking densities of fingerling trout can be reduced to match lowered water levels and still produce a viable fishery during the season of release, if reservoirs are not completely drained to meet downstream irrigation needs. However, fingerling trout release almost always fail to meet fishery objectives when both tui chub and low water levels exist.

FISHERY RESTORATION STRATEGIES

Chemical treatment of Diamond Lake

What is proposed
Application of rotenone to Diamond Lake in early Fall would kill most gill-breathing animals, including all fish. The naturally reproducing population of tui chubs would be eliminated. Powdered rotenone would be dispersed from boats in all open water parts of the lake and liquid rotenone mixed with water would be sprayed in vegetated shoreline areas. The lower ends of tributary streams would also be treated with liquid rotenone. Rainbow trout would be restocked the following Spring

Problem addressed
Competition for food between trout and tui chubs which reduces trout survival and growth to unacceptable levels.

Preconditions:

- successful NEPA review with a finding of no significant impact
- securing funding for rotenone purchase and other expenses
- drawdown of the lake by eight vertical feet

Costs
Materials:

Purchase and ship about 226,000 pounds of powdered rotenone and 250 gallons of liquid rotenone to the lake.

$355,000

Rent or purchase heavy equipment to load and unload the bags of rotenone, the rotenone dispersal equipment, boats to carry and disperse the rotenone and safety equipment. The detailed equipment list is extensive. Some of the equipment, especially pumps, is very specialized and expensive.

Equipment costs could be as much as $100,000.

Preparation:

Complete an EA or EIS for the NEPA process. $???????

Restore the 1954 canal to drain down the lake by about 8 feet to reduce the volume treatment cost and cut off outflow of rotenone-treated water into the outlet.

$ 350,000

Application:

Arrange for personnel to carry out the treatment, including lodging, meals; practice techniques and test equipment $??????

Post-treatment:

Clean-up of dead fish $??????
Supplemental feeding of eagles $??????

Measure of success:
Elimination of tui chubs and golden shiners; return to high rate of survival for stocked trout

Probablity of success:
Based on experience at Diamond Lake and at many other lakes and reservoirs, Diamond Lake has no conditions which would cause treatment to be unusually difficult or which would reduce the high probability of success.

Consequences and risks:

There would be a loss of angling opportunity the summer preceding treatment, since no trout would be stocked that spring. During and after treatment in fall no fish would be present; catchable and fingerling trout would be stocked the Spring after treatment, with fingerlings entering the fishery in Fall. The fishery should be almost fully restored the second spring after treatment.

Lake drawdown of eight feet would interrupt the supply of water that is currently withdrawn from the lake and disrupt aquatic vegetation and animals down to that level. Lake Creek would be subjected to unseasonally high flows at drawdown, then be de-watered for a short distance below the lake while the lake refills.

Most gill breathing animals would be killed, including all fish. Some benthic species, such as crayfish and snails are resistant to rotenone. Invertebrate populations in general recover quickly after rotenone treatment. Zooplankton are susceptible to rotenone, but they should recover in 2-12 months. Phytoplankton are not directly affected by rotenone but nutrient increases from decaying fish and lack of grazing by zooplanton favor temporary increases in abundance

Rotenone does not directly affect birds or mammals but the treatment would temporarily reduce available habitat and temporarily reduce the food supply for fish eating birds and mammals.

- Bald Eagles

Currently, two pairs of Bald Eagles are present on Diamond Lake and have established nesting territories. Eagles typically arrive at Diamond Lake in February/March to begin nesting activities. Egg laying begins in March and young are fledged by July 1. The two pairs of eagles have fledged an average of 0.7 young per year over the past five years. The adult eagles plus the fledged young remain at Diamond Lake until November when they migrate out of the area. Depending on the time of year and availability of food these eagles utilize fish, waterfowl and carrion (elk and deer) as primary food sources. The rate of successful fledgling production may be reduced by treatment. The US Fish and Wildlife Service will direct mitigation measures for eagles if the lake is to be chemically treated.

- Osprey

Approximately 3 - 9 pairs of osprey utilize Diamond Lake for nesting. Nest sites are distributed around the lake in dead trees (snags). Osprey begin arriving at Diamond Lake in April to begin nesting activities. Egg laying begins in May and young are fledged by August. Osprey feed exclusively on fish available in Diamond Lake and migrate out of the area in October.

- Mustelids

Several species of mustelids including otter, mink and raccoon inhabit the Diamond Lake area. Approximately 15-30 otter inhabit the Diamond Lake area during the summer months. Like all mustelids, these species are omnivores that can and do utilize a variety of food sources, with the otter being most reliant on the fish resources of the lake.

- Waterfowl

Several species of waterfowl including breeding and non-breeding populations, utilize Diamond Lake and feed on either the fish or invertebrate resources of the lake. These include Barrows Goldeneye (Oregon sensitive species), Bufflehead (Oregon sensitive species), mallard, cormorant, and common loon.

Several species of reptiles and amphibians inhabit Diamond Lake and may be affected by any of the management options being considered. Larval amphibians and gill-breathing adults have a relatively high resistance to rotenone, however loss of prey species may indirectly impact them. Reptiles are not directly affected by rotenone but they too may be indirectly impacted by loss of prey organisms. A field study is planned to begin in April 1996 to determine which species are present in and around Diamond Lake as well as life history patterns.

Rotenone toxicity to humans and other mammals is very low. Direct contact causes temporary skin, eye, and mucus membrane irritations. Only the crew working on the project are at risk of exposure, and that risk can be virtually eliminated through the use of protective clothing, respirators, and goggles.

The risk of discharge of contaminated water through the outlet and down Lake Creek is minimized by drawdown of the lake, creating space in the lake basin for refill while the treated water detoxifies over the span of four to six weeks. Refill of the lake to a level where spill down the outlet occurs took several months in 1954.

No irreversible effects of chemical treatment are expected since permanent physical alteration of the land or water will be avoided and there will be rapid detoxification of the rotenone (about 30 days).

Responsible parties

ODFW, with assistance from Umpqua National Forest

INTERIM STRATEGIES

Several management actions may be tried while awaiting resolution of the central issue of competition with tui chubs. None will return the fishery to meeting current management objectives, but they may provide some increase in survival and slow decline of the fishery.

Increase the number of fingerlings

What is proposed

Increase the number of fingerlings released in routine stocking, compensating for low survival rates. The annual hatchery releases of 400,000 fingerlings provided about 56,000 harvestable trout in 1994, compared to an average of 270,000 fish in earlier years. A release of over 2 million fingerlings would be needed to meet current management goals assuming the survival rate does not decline further with increased stocking rates. The fishery and related potential impacts would be closely monitored to evaluate any benefits and consequences.

Problem addressed:

The current survival rate of rainbow trout fingerlings is less than 25% of the expected rate.

Preconditions:

Additional funding and hatchery facilities need to be identified for increased fingerling releases. Creel surveys and fish population sampling on the lake and downstream areas should be completed on a regular basis, including the lake and downstream areas.

Cost:

The total cost for the current hatchery program of 400,000 rainbow trout is $24,000 or about 5 1/2 cents per fingerling. The total cost for 2 million fingerlings would be over $100,000. Cost and availability of fingerlings will vary depending on production capability and other program needs. Large scale increases in fingerling trout at Diamond Lake may only be possible at the cost of other trout fisheries dependent on these fish or contract rearing since public trout hatcheries in Oregon are currently at capacity.

Measure of success:

As an interim measure, survival rate to harvest in excess of 40% of fingerlings stocked would constitute a substantial improvement over the current condition. The actual catch level achieved would depend on the niumber of fingerlings stocked, which will be limited by both financial and opportunity costs to trout hatchery programs.

Probability of Success:

This strategy has a low probability of success, based on the assumption that the food production is already limited for fingerling trout. Survival would likely diminish with large increases in the number of fish stocked, providing only a small increase of trout for the fishery. Trout growth may also decrease and cause the return rate to the fishery to decline even more than existing conditions. Increases in the tui chub population are difficult to predict, but recent information suggests it is expanding rapidly with a large number of fish in the same size range as trout fingerlings. Even with large increases of fingerling trout stocked, tui chub abundance will remain higher than the total trout population at any time.

Risks and consequences:
The return rate to the fishery will likely not be worth the additional production costs.

Effects of higher stocking rates on the number of hatchery trout leaving the lake likely depends on numerous factors, not the least of which is survival of fish stocked. However, there has been no indication of significant impacts on downstream native trout or steelhead from the millions of hatchery trout released in previous years. The potential risk to the existing salmonid populations downstream and their long-term productivity is likely not significant. Monitoring downstream areas for presence and abundance of hatchery rainbow trout would provide some indication of possible impacts, and these results would be helpful in determining actual outmigration numbers.

Responsible parties:
ODFW is the responsible party related to fish stocking programs.

Increase the size of fingerling trout stocked

What is proposed:
Increase the size of fingerling rainbow trout released in Diamond Lake. Rainbow fingerlings are currently released at 50 per pound (3-4") during the first week of June or when the lake temperature reaches about 60 degrees F. The fingerlings would be raised to a larger size (20 per pound) for release during the same period under this proposal.

Problem addressed:
The current survival rate of rainbow trout fingerlings is less than 25% of the expected rate.

Preconditions:
Funding and logistical feasibility of the hatchery system to produce large fingerling rainbow of Oak Springs stock must be determined. An evaluation approach must be identified and funding found.

Costs:
Total cost for the current hatchery trout program for Diamond Lake is $24,000 for 400,000 fingerings. The individual cost of each rainbow fingerling raised to 50/lb is about 5 1/2 cents. Estimated cost for raising larger fingerlings would be about double or 11 cents per fish released. The total cost of this proposal would be about $30,000 which would include an experimental group of about 50,000 fish raised to a larger size. The additional cost to finmark this experimental group for evaluation of benefits is about $500. Increases in fingerling trout size on a large scale may only be possible with a reduction of releases at other trout fisheries dependent on these fish or by contract rearing by a private hatchery at increased cost.

Measure of success:
As an interim measure, survival rate to harvest in excess of 40% of fingerlings stocked would constitute a substantial improvement over the current condition. The actual catch level achieved would depend on the niumber of larger fingerlings stocked, which will be limited by both financial and opportunity costs to trout hatchery programs.

Probability of Success:
This strategy has a medium probability of success, based on the assumption that there will be natural food production available for trout which are large enough to successfully compete with tui chubs. Increasing the size of trout stocked should eliminate most of the bottleneck associated with availability of zooplankton, but both trout and chubs will compete for benthic organisms as chub abundance increases. Montana and other western states report better survival with fingerlings in the 20 - 25 per pound range than with smaller fingerlings when stocked into lakes with tui chubs.

Increases in the tui chub population are difficult to predict, but 1995 data suggests that they are rapidly expanding in numbers of both spawners and young of the year fish.

Information from years just prior to 1954 lake treatment shows a very steep decline of available food production. Even though survival of trout stocked at a larger size may be greater than that of smaller fingerlings, the advantage may soon disappear as the chub population increases.

Risks and consequences:
The risk of this program is primarily cost related. If larger-sized fingerlings are stocked, but the survival rate remains low, then the number of harvestable trout will not increase and the effort will not have been cost-effective.

The rate of trout out-migration from Diamond Lake may also increase with larger fingerlings released at the lake. However, there is currently no indication of rainbow trout leaving Diamond Lake and residing with the other species present in Lake Creek despite the fact that the only annual supplementation of fish into the stream would be from the Diamond Lake stocking program. Other species of trout are present in Lake Creek in good numbers. Further downstream the existing populations in the river, streams and reservoirs are a mix of species including brown, brook, and rainbow trouts, kokanee, and tui chub. The nearest distance for possible interaction of Diamond Lake outmigrants with anadromous fish populations is 35 miles downstream at the base of Soda Springs dam. The probability of large numbers of stocked rainbow from Diamond Lake impacting genetic resources of salmonids downstream is insignificant considering the distance and the existence of eight hydro-electric projects. Any further risk to the steelhead or trout in the North Umpqua River from this proposal is very unlikely, especially considering the relatively small percent of the total release of larger-sized fingerlings proposed (150,000 over 3 years) compared to the historical stocking numbers of domestic rainbow (19 million over 40 years).

Monitoring of Lake Creek and Lemolo reservoirs for finmarked rainbow trout will provide information regarding whether significant numbers of fingerling trout migrate from the lake. Modifications of the scheduled releases could be made based on results of these surveys.

Responsible parties:
ODFW is responsible for fish stocking.

Use catchable rainbow trout provide additional fish for harvest

What is proposed:
Modify the current trout stocking program to include more catchable-sized trout. The present hatchery fish releases contribute to the fishery primarily after growing in the lake for several months; catchable hatchery trout are immediately available to the fishery. Numbers and release times for these 8-10" fish will be based on historical fishery levels and seasonal catch rates. The overall trout harvest would depend primarily on the annual stocking level, with a goal of 70% return rate to the fishery.

Problem addressed:
The current survival rate of rainbow trout fingerlings is less than 25% of the expected rate.

Preconditions:
Funding and logistical feasibility of the hatchery system for large scale production of catchable trout must be determined or catchable trout must be shifted from other fisheries. An evaluation approach must be identified and funding found.

Costs:
The total cost for the current hatchery trout program for Diamond Lake is $ 24,000. The cost to raise a legal-sized trout in a hatchery is $ 0.85, compared to $ 0.06 for a fingerling rainbow. Stocking to meet management plan catch objectives (270,000 harvested) would increase the total cost to $340,000 for release of 400,000 harvestable trout, if catchable trout contributed at a 70% rate. The number of trout released and estimated hatchery program costs could be lower because of the overall harvest rate of the fishery or reduction of the catch objective.. An estimated $90,000 annually would be needed to provide harvest levels similar to the 1994 fishery (57,000 harvested) and over $250,000 for a trout fishery comparable to 1989 (170,000 harvested). These estimates do not include any facility improvements or program costs that may be required to raise larger-sized fish at the hatcheries. Production of catchable rainbow on a large scale may only be possible by reducing releases for other trout fisheries.

Measure of success:
As an interim measure, survival rate to harvest of 70% of catchable trout stocked would constitute a substantial improvement over the current fishery if large numbers of catchables are available. The actual catch level achieved would depend on the niumber of catchable trout stocked, which will be limited by both financial and opportunity costs to trout hatchery programs.

Probability of Success:
This strategy requires only a few weeks of high survival rate for the trout releases to provide harvestable fish. Legal-sized trout would be available immediately after each

stocking period. Larger-sized trout feed on food available in the lake that has not yet been severely limited by the tui chub population. Return rate to the fishery based on total numbers of fish released will be higher and more stable compared to the current fingerling program. Stocking levels and liberation times could be adjusted within season to meet catch objectives.

This strategy has a medium probability for success, based primarily on how many large trout could be released annually into the lake and the actual harvest rates. Funding for large scale releases of catchable trout is uncertain at best. A creel survey would provide fishery effort and catch data to determine if management objectives are being met. The current management goals include the opportunity for anglers to harvest rainbow trout that average 12" in length and weigh nearly one pound. While catch objectives could be met if sufficient numbers of fish were available, the size objectives could not.

Risks and consequences:

With this strategy, the total numbers and biomass of fish in the lake, including trout and tui chub, would be the highest level since the 1950's. The available food source may decrease at a faster rate than the pre-treatment years. The long-term effects related to the lake's productivity is unknown, but likely not as severe as total chemical treatment which occurred in 1954. Following chemical treatment lake productivity quickly rebounded.

A risk related to fishery management goals with this strategy is the possible continued decline of angler effort and satisfaction. The fishery will now rely primarily on the quality of the fish raised at the hatchery, not in the lake. However, in lieu of this strategy, Diamond Lake's ability to produce a quality trout fishery will decline with increasing tui chub abundance, making this a moot issue. The actual fishery benefits from the higher hatchery program investments should be closely monitored, as it is likely to decline over time with increased abundance of tui chub and decreased food available for trout.

The risk to downstream fish populations may increase, if outmigration of larger-sized fish occur at a similar or higher rate than fingerling releases. More frequent stocking periods throughout the year may increase the chances of disoriented hatchery fish moving downstream on a regular basis. The large population size and severely reduced natural food production may also cause an increased outmigration from the lake. Catchable rainbow trout escaping the lake will be much easier to identify than those which escape as fingerlings and rear in the wild. Successful rearing competition and spawning interaction with other trout in streams and reservoirs may also increase based solely on larger-sized hatchery fish having direct competition with relatively smaller-sized wild trout and the possibility of increased migration distances.

<u>Responsible parties:</u>
ODFW is responsible for fish stocking.

ALTERNATIVE STRATEGIES

If chemical treatment of Diamond Lake is not authorized, or if possible treatment is delayed for many years, more radical changes in management may be necessary in order to maintain a trout fishery. The character of the fishery would change, since only the Oak Springs stock is known to be capable of providing the growth and catchability necessary to meet current management objectives.

Introduce different strain of rainbow

What is proosed:
Substitute a new different stock of rainbow trout for all or some of the Oak Springs stock currently used at Diamond Lake. Two options are possible: use a stock already available from hatcheries in Oregon or elsewhere, or develop a new "wild" stock.

Problem addressed:
The current survival rate of Oak Springs stock rainbow trout fingerlings is less than 25% of the expected rate. Competition with tui chubs is or will in the future limit survival of Oak Springs rainbow trout; if chubs cannot be eradicated a more survivable stock will be needed.

Precondition:
Candidate stocks capable of persisting in the face of tui chub competition must be identified and funding arranged for hatchery propagation. Chemical treatment must be unavailable or delayed for several years.

Costs:
The total cost for the current hatchery program for Diamond Lake is $24,000. The actual cost of releasing a new stock of rainbow in Diamond Lake could vary considerably based on the origin of the fish, broodstock collection, rearing facilities, and other factors. If another broodstock is readily available and fish are reared to the same size at release, costs would be relatively the same. The cost of rearing a yearling fingerling or larger fish is higher because of additional food and personnel needs at the hatchery. For example, Williamson River rainbow trout spawn several months later than the Oak Springs stock and therefore, can not be reared to the optimum release size by June. These fingerlings are released as larger yearlings the following June at about double the cost (11 cents vs. 5 1/2 cents). Any additional activities needed to collect wild trout for broodstock or purchase eggs from other programs would be added to this rearing cost. "Wild" stocks are typically more expensive to propagate than domesticated stocks such as the Oak Springs stock.

Measure of success:
New objectives for catch, effort, and size adopted and met; no biological impacts downstream from Diamond Lake.

Probability of success:
This strategy has a low probability of restoring the Diamond Lake fishery to meet current management goals. The opportunity to provide a large number of harvestable trout from a fingerling stocking program is very limited under the current situation with tui chubs. It is unlikely that the management goal of 270,000 trout averaging 12 inches in length will ever be achieved in the presence of a tui chub population. The chances of a high percent of the rainbow trout fingerlings out-competing a prolific and natural spawning chub population

in the lake is relatively low and will continue to decline as the chub population size increases. Any new rainbow trout stock would be selected on the basis of an expectation to successfully compete with tui chubs for food and to consume chubs as the trout grow larger. However, the trout population could never eliminate nor control the tui chub population. If fingerlings survived well, the resultant trout fishery would likely be on slower growing, less readily catchable trout, but which produced more large fish than the current fishery. Under this scenario a different set of management objectives would be in order.

A recently developed hatchery broodstock derived from Williamson River wild rainbow trout is available within the ODFW hatchery system. This stock evolved with tui chubs in a lake-rearing environment and has demonstrated the ability to survive in competition with chubs. Some 12,000 fingerlings of this stock were experimentally introduced into Diamond Lake in 1995 to assess their performance.

The only probability for success would be to establish a fishery based on some reduced number of rainbow trout. The management goals for angler effort would reflect the opportunity to catch larger-sized rainbow, but at an overall lower harvest rate. Food production available to trout would continue to decline until tui chub and available food eventually reach some ecological balance.

Risks and consequences:

The risk of impacting salmonids downstream of the lake would increase only if the survival rates, outmigration rates, competitive strength, genetic resources, and other factors of the new rainbow stock allowed a significantly higher number of fish into the North Umpqua system. The risk is even further reduced for anadromous species that are not present until 35 miles downstream. Outmigrating rainbow would have to survive several unscreened hydroelectric diversions and turbines, competition with other fish species, reservoirs and bypass reaches, and angler harvest to reach the uppermost section where steelhead and other anadromous fish are present. Then the fish must successfully seek and spawn with other trout or steelhead species to degrade the genetic viability of a wild population. The probability of this occurring and being a significant additional risk needs to be placed in prospective with regards to the millions of domestic rainbow that have been historically stocked in Diamond Lake with no apparent significant effects downstream.

The ability to monitor the upper basin (Lake Creek and Lemolo Reservoir) for any indications of significant changes in existing fish populations allows for relatively quick modifications of the hatchery program if hatchery fish are detected downstream. The initial potential impact would only involve exotic brook and brown trout populations, not the wild anadromous fish species located below Soda Spring dam.

Responsible parties:
ODFW is responsible for fish stocking.

Introduce new species of trout (not rainbow)

What is proposed:
Introduction of a species of trout other than rainbow which could be expected to persist in the face of competition with tui chubs and provide a trout fishery. Brown trout, kokanee salmon, or other species could be investigated.

Problem addressed:
The current survival rate of Oak Springs stock rainbow trout fingerlings is less than 25% of the expected rate. Competition with tui chubs is or will in the future limit survival of Oak Springs rainbow trout; if chubs cannot be eradicated a more survivable stock will be needed

Costs: The costs would vary considerably depending on the species, available hatchery broodstocks, and stocking program. The cost per pound of hatchery trout in Oregon ranges from $2.61 to $3.27. Hatchery programs currently exist in Oregon for brown trout, brook trout, cutthroat trout, kokanee, and Atlantic salmon.

Preconditions:
ODFW would have to recommend and receive approval to change the existing fish management plan adopted by the Commission in 1990. Further review would be needed regarding the new introductions of exotic species in the North Umpqua prior to formal recommendations for the new stocking programs. Approaches and funding must be identified for creel surveys and fish population sampling.

Measure of success:
New objectives for catch, effort, and size adopted and met; no biological impacts downstream from Diamond Lake.

Probability of Success:
There is a very low probability that significant natural spawning of any trout species will occur in Diamond Lake. The lake's fishery would still rely on stocking of hatchery fish and their survival and growth rates. Natural spawning populations of brown trout, brook trout, and kokanee are already present in Lake Creek and the upper North Umpqua below Diamond Lake, but tributaries into the lake are relatively small and limited in available spawning habitat.

Stocking any species of fingerling trout would require an adequate food source for good survival and growth. Competition by tui chub would still be a major limiting factor for overall trout productivity. Larger brown trout would utilize tui chub as a food source, but would not control or eliminate the population. Before reaching a size to consume tui chubs, brown trout would still have to survive competition for food; there is no indication that they will survive better than rainbow trout. Brook trout and kokanee would not compete well with large numbers of tui chub in a lake with especially low zooplankton levels.

Cutthroat trout and Atlantic salmon would also have to compete with tui chub in the lake and could possibly utilize the population as a food source. Again, the tui chub population size would not be significantly reduced or controlled by trout predation.

The success for any stocking any new species could easily be measured through creel surveys and fish population sampling in the lake.

Risks and consequences:
The introduction of any new trout species would still be in direct competition with the tui chub and may not survive as well as the current rainbow trout program. The introduction of another exotic species in the basin risks impacts to the existing populations within and downstream of the lake. The outmigration rate of these species is unknown, but would probably be similar to the rainbow stocks. The potential for cutthroat trout or Atlantic salmon establishing large wild populations in the upper North Umpqua is not known, but assumed to be unlikely. Hybridization with native rainbow trout is possible for cutthroat.

Angler effort and trout harvest levels for any of these species would probably not meet the current management goals, and may actually cause further declines to the fishery. A two-tier fishery with tui chub and trout would probably still remain at some lower level than existing conditions, but with a new species of trout and many unknown affects in and below the lake.

Responsible parties:

ODFW is the responsible party related to introduction of new species into lakes and streams.

Chemically treat selected areas of Diamond Lake annually to reduce chub abundance

What is proposed:
Annual treatment of shorelines with rotenone to reduce tui chub abundance. In late spring and early summer where adult and fry tui chub congregate near along the shore. Large numbers of chub can be removed.

Problem addressed:
The current survival rate of Oak Springs stock rainbow trout fingerlings is less that 25% of the expected rate. Competition with tui chubs is or will in the future limit survival of Oak Springs rainbow trout unless relief from competition is found. Total chub eradication would be expensive and have much greater temporary impacts to the ecosystem.

Preconditions
An EA would have to be completed to address the minor, short term impacts to the lake ecosystem. Funds would have to be identified for rotenone purchase and salaries.

Costs
Materials

Liquid rotenone for annual chemical treatment
Pumps and hose for dispersal
Boats to haul the application equipment and personnel.

Cost: $1,200 annually (using existing equipment)

Preparation

Prepare an EA for the NEPA process

Surveys to locate spawning areas and establish time of spawning would be done by district personnel.

Personnel time

Two-two person teams to apply rotenone weekly in May and June each year. Use of volunteers would offset costs.

Cost: $20,000 annually

Measure of success

Survival of fingerling trout to harvest in excess of 50% of fish stocked

Probability of success

The intent of this strategy is to improve trout survival by reducing competition for food and rearing habitat. Trout species such as rainbow, cutthroat, brown and brook trout all rely heavily on littoral (shoreline) zones in lakes and their associated food base as an important component in their rearing habitat. It is currently believed that the abundant tui chub population out competes rainbow trout fingerlings for food and space, resulting in poor trout survival and a decline in the fishery. Success of this strategy would rely on removing enough tui chubs to eliminate this bottleneck to trout survival.

This strategy likely has a low probability of success for meeting current management objectives. It is unlikely that enough tui chubs could be removed on an annual basis from Diamond Lake using only partial removal methods, such as rotenone treatment, to reverse the current decline in trout survival. Tui chub control was attempted a Diamond Lake with gillnets and partial rotenone treatment during the period 1946-1950. The removal of over 68 million chubs during that time failed to improve trout survival and growth. In addition, nearly 50 years of experimentation regarding partial control of tui chub at Central Oregon lakes and reservoirs has failed to provide significantly measurable benefits to trout survival and growth.

Risks and Consequences

Risk of killing non-target fish with use of partial rotenone treatment is low because spawning tui chub are very concentrated and trout are not abundant due to elevated water temperatures. Gill-breathing aquatic insects and crayfish in the treated area would be killed. Birds and mammals are not impacted directly by rotenone. There would be a reduction in the availability of tui chub as prey for ospreys and eagles. Overall, there would be no significant impact on the lake's fauna based on past experience with partial rotenone treatment. There would be financial risks associated with spending significant amounts of time and money in tui chub control if efforts were largely unsuccessful at improving trout survival.

Responsible parties

ODFW is responsible for fish management. ODFW would likely seek volunteer assistance from a variety of sources including USFS, angling groups, lodge owners, etc.

Partial control of tui chub by netting

What is proposed:
Tui chubs would be removed from Diamond Lake annually by capture in seines, gillnets or trapnets. Chubs would be disposed of at a site acceptable to the USFS and Department of Environmental Quality (DEQ).

Problem Addressed:
The current survival rate of Oak Springs stock rainbow trout fingerlings is less than 25% of the expected rate. Competition with tui chubs is or will in the future limit survival of Oak Springs rainbow trout unless relief from competition is found.

Preconditions:
A disposal site for the tui chubs removed from the lake acceptable to the DEQ and USFS would need to be determined and funds identified for purchase of nets and hiring of personnel prior to initiation of this strategy.

Costs:
Difficult to calculate, but likely significant if paid staff were utilized for the effort. Removal of chubs from a lake this size (>3000 acres) using only nets or seines has never been attempted in Oregon. Removal efforts would be required annually throughout much of the summer when the lake is ice-free. This strategy would be very labor-intensive. If three or more two-person crews were necessary in the effort, costs could easily exceed $50,000 annually (6 seasonals at $2500/month for 4 months = $60,000). In addition, if a local site could not be found for disposal of the chubs, transportation to a fish processing plant or other site acceptable to the DEQ would increase annual costs.

Measure of success:
Survival of fingerling trout to harvest in excess of 50% of fish stocked.

Probability of Success:
The intent of this strategy is to improve trout survival by reducing competition for food and rearing habitat. Trout species such as rainbow, cutthroat, brown and brook trout all rely heavily on littoral (shoreline) zones in lakes and its associated food base as an important component in trout rearing habitat. It is currently believed that the abundant tui chub population out competes rainbow trout fingerlings for food and space, resulting in poor trout survival and a decline in the fishery. Success of this strategy would rely on removing enough tui chubs to eliminate this bottleneck to trout survival.

This strategy likely has a low probability of success for meeting current management objectives. It is unlikely that enough tui chub could be removed on an annual basis from Diamond Lake using only partial removal methods such as netting, to reverse the current decline in trout survival. Tui chub control was attempted at Diamond Lake with gillnets and partial rotenone treatment during the period 1946 - 1950. The removal of over 68 million chubs during that time failed to improve trout survival and growth. In addition, nearly 50 years of experimentation regarding partial control of tui chub at Central Oregon lakes and reservoirs has failed to provide significantly measurable benefits to trout survival and growth.

Risks and Consequences:
This strategy would cause no risk to indigenous fish populations downstream of Diamond Lake. Hatchery trout encountered in trap netting or seining of tui chub could be released back into the lake unharmed. There would be financial risks associated with spending significant amounts of time and money in tui chub control if efforts were largely unsuccessful at improving trout survival.

Responsible Parties:
ODFW is responsible for fish management. ODFW would likely seek volunteer assistance from a variety of sources including USFS, angling groups, lodge owners, etc.