MYSIS-GAMEFISH STUDIES

Federal Aid Project F-83

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Job Progress Report

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Colorado Division of Wildlife

Fish Research Section

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JOB PROGRESS REPORT

State: Colorado

Project No. 02-01-131 Name: Statewide Fish Research

Study No. F-83 Title: Mysis-Gamefish Studies

Period Covered: July 1, 1984 - June 30, 1985

Study Objective: Develop guidelines for managing lakes with *Mysis* populations.

The *Mysis*-gamefish project was given Division approval early in 1984, and was scheduled to run for a 2-year period from May 15, 1984 to June 30, 1986. Contractual obligations to the Bureau of Reclamation to complete the Twin Lakes studies under the Fryingpan-Arkansas Fish Research Investigations extended through June 30, 1984. Sample processing, data analyses, and completion of the final report for the Twin Lakes studies extended to August 1984. In effect, the completion of the Twin Lakes studies prevented the effective planning and initiation of the *Mysis*-gamefish studies within the time frame allowed.

As a result, field work during the 1984 field season was limited to a few preliminary sample surveys. Key equipment breakdowns further inhibited field sampling during the fall of 1984. The study narrative for the *Mysis*-gamefish project, which summarizes background information, justification for research, study objectives, methods and expected results and benefits, was completed in March 1985 (Appendix A).

This segment report includes preliminary analyses of data collected in 1983 and 1984 on nine lakes and reservoirs that received *Mysis* introductions. Developments within the Division of Wildlife dictated that activity within this project be suspended in fiscal year 1985-86 due to lack of available research personnel and funding. Thus, the database necessary to fulfill most of the substudy and job objectives described in the study narrative could not be acquired within the time frame of this study. Preliminary information on some of the *Mysis* lakes and reservoirs were combined with the available literature to develop management alternatives for the fisheries of these waters.

Substudy Objective No. 1: To determine the status of zooplankton and *Mysis* populations in selected lakes and reservoirs that have had *Mysis* introductions.

Job 1: To determine the success or failure of past *Mysis* introductions, the relative abundance of the population, and its status given known introduction dates and past density data.

RESULTS

Mysis shrimp have been introduced into a variety of habitats in Colorado including small, shallow, high lakes to very large and deep coldwater reservoirs. To understand the potential role of *Mysis* in Colorado and determine a management plan for lakes with *Mysis* populations, it is necessary to determine the success of *Mysis* introductions in these different habitats. Fifty-five waters are known to have received introductory plants of *Mysis* shrimp either directly or from downstream importation (Table 1). Twenty-four of these waters have been surveyed for the presence of *Mysis* one or more times since the introduction. Shrimp were subsequently sampled in 17 of the 24 lakes, of which 13 have established populations of *Mysis*. Established populations of *Mysis* are defined as those that are well dispersed from any introduction point and appear to be self-sustaining over time. *Mysis* were established in these lakes 4-13 years after introduction, with an average time lag of 10 years. *Mysis* shrimp have clearly become established in the large, coldwater reservoirs. They have also had some success maintaining populations in some of the high-altitude lakes, though it is less certain how widespread this success has been. *Mysis* appear to have been successfully imported via transmountain diversions into some of the Front Range reservoirs. Case by case observations of some of the lakes listed in Table 1 indicate *Mysis* may have adapted fairly well to most of the lake environments into which they were planted.

Table 1. Summary of Colorado lakes and reservoirs planted with Mysis shrimp.

Water	County	S.Area (ac)	Depth (ft)	Elev. (ft)	Year(s) planted	Date checked	Fish spp[a]	Status
Horsetooth	Larimer	1,875	203	5,430	1971-74 IMD[c]	Periodic	R,K,NP,M,L,SMB, LMB,W,YP,WB,AMS	Mysis present in 1981
Chambers	Larimer	300	91	9,153	1971-74	8/75	R,K,L	Mysis sparse
Forest	Larimer	13	39	11,020	1971-74		R,N	
Sugar Bowl	Larimer	8	50	10,791	1971-74	1981	M,B	Mysis absent in fish stomachs
U. Camp	Larimer	39	77	10,732	1971-74	1982	M,B	Mysis absent in fish stomachs
Rawah #4	Larimer	26	149	11,474	1971-74		N	
Mary	Larimer	42	32	8,046	IMD	1984	R,K	Water source-Granby Mysis present
Carter	Larimer	1,144	160	5,759	IMD	1981	R,K,N,W YP,LMB,L	Water source-Grand Lake-B.Thompson Mysis present
Estes	Larimer	185	44	7,468	IMD	1981	R,L	Water source-Grand Lake-B.Thompson Mysis present
Aqua Fria	Jackson	28	59	10,040	1971-74		B,M	
Blue	Jackson	22	132	9,815	1971-74		B,M	
Twin	Jackson	23	46	9,865	1971-74		N,M,B	
Katherine	Jackson	23	115	9,859	1971-74		M,B	
Rainbow	Jackson	96	91	9,854	1971-74	1976	R,N	Mysis absent in trawl
Roxy Ann	Jackson	63	126	10,204	1971-74		N,GO	
Peggy	Jackson	10	31	11,165	1971-74		N	
Kelly	Jackson	21	43	10,805	1971-74		GO,GR	
U.Big Creek	Jackson	101	30	9,009	1971-74		R,K,N,L,B	
L.Big Creek	Jackson	377	57	9,000	1969-72	1975-76 Periodic	R,K,M,L	Mysis present; none observed in lake trout stomachs

Table 1. Summary of Colorado lakes and reservoirs planted with *Mysis* shrimp (continued).

Water	County	S.Area (ac)	Depth (ft)	Elev. (ft)	Year(s) planted	Date checked	Fish spp[a]	Status
Cheesman	Douglas	875	190	6,842	1971-74	Periodic	R,L,K,YP	
Gross	Boulder	413	280	6,990	1971-74		R,L	
Little Echo	Gilpin	13	75	11,185	1971-74		R,M	
Silver King	Chaffee	16	11	12,640	1972		N	
Willis	Chaffee				1972		N	
Clear Creek	Chaffee	407	50	8,878	1971		R,K,L	*Mysis* absent
Timberline	Lake	6	28	10,950	1971	1976	N,B	*Mysis* absent in fish stomachs
Turquoise	Lake	1,814	128	9,870	1972	1977-80 & 1983	R,N,L,M,K,B	*Mysis* present in 1983
Deckers	Lake	14	9	11,350	1972		M,B,N,Sp	
Chalk	Lake	14	22	12,250	1972	1983	R	*Mysis* present
Crystal	Lake	10	13	9,800	1972	1983	R,L	*Mysis* absent
Upper and Lower Twin	Lake	3,137	100	9,200	1957	Periodic	R,M,L,B	*Mysis* present by 1969-70
Crater	Grand	20	78	10,320	1972		M,B,N	
Grand	Grand	515	266	9,000	1969-71	8/75 Periodic	R,K,M,B,L	*Mysis* present since 1975
Shadow Mountain	Grand	1,360	36	8,367	d	8/75 Periodic	R,K,L,M	Water source-Grand Lake; *Mysis* present since 1975
Granby	Grand	7,250	220	8,280	1971	8/75 Periodic	R,K,M,L,GR	*Mysis* scarce-1975 abundant 1979
Pierre	Pitkin	47		12,210	1972		N	
Capitol	Pitkin	22	100	11,600	1972		N	
Chapman Dam	Pitkin	23	25	9,850	1970		R,B,N	
Lost Man	Pitkin	7	23	10,640	1971		R,B	
Diemer	Pitkin	40	8	8,500	1970		R,B	
Sellar	Pitkin	20		9,000	1970	8/76	R	*Mysis* absent
Ivanhoe	Pitkin	100		10,200	1970		R,M	

Table 1. Summary of Colorado lakes and reservoirs planted with *Mysis* shrimp (concluded).

Water	County	S.Area (ac)	Depth (ft)	Elev. (ft)	Year(s) planted	Date checked	Fish spp[a]	Status
Gold Dust #1-#5	Eagle	2-25	10-99	11,400+	1972		N	
Blodgett	Eagle	25	94	11,750	1972		N	
Bowl of Tears	Eagle	20	101	12,050	1972		N	
New York	Eagle	40	62	11,000	1972		N	
Ruedi	Eagle	1,100	279	7,600	1970	8/76 1977-78 1983	R,K,M,L,B	*Mysis* absent in 1976-78; present in 1983
Homestake	Eagle	340		10,100	1972		R,N,B	
Jefferson	Park	125	100	10,707	1972	7/76 10/83	R,M,	*Mysis* absent-1976; present-1983
Pass	Summitt	3	4	11,992	1970		None	
Dillon	Summitt	3,153	240	9,200	1970	8/79 1983-84	R,K,L,B	None in 1977-78; *Mysis* present since 1979
Green Mountain	Summitt	2,125	249	7,950	1974	8/79 1983,84	R,K,M,L,B	*Mysis* present in 1979; absent in 1983-84
Deep	Garfield	30		10,450	1972		R,M,B	
Stillwater	Garfield	88		10,225	1974		R,L,B,N,WF	
Taylor	Gunnison	2,033	150	9,330	1973-74	1981	R,M,K,NP,L	*Mysis* present

[a]see Appendix B for abbreviation detail
[b]*Mysis* planted some time during 1971-74, not all 4 years
[c]*Mysis* introduced via intermountain diversions
[d]*Mysis* introduced via direct downstream flows

Twin Lakes (Lake Co.)

Twin Lakes were the first Colorado waters to receive *Mysis*. These shrimp were transported from Clearwater Lake, Minnesota, in 1957, and were stocked into Lower Twin Lake. The objective of the introduction was to improve the food chain for trout, specifically mackinaw or lake trout, and to supplement the diet of the other salmonid species (Klein 1957). The initial plant of 600-1,000 individual shrimp reproduced, and migrated into the upper lake via a short stream channel deepened for irrigation development. The Twin Lakes population was well established by 1970, and was abundant enough to serve as seed stock for further introductions into other lakes and reservoirs (Finnell 1972). By 1976, Griest (1976) demonstrated that *Mysis* shrimp had become a major constituent in the lake trout diet, and had improved the growth of immature lake trout. Studies of *Mysis* shrimp population dynamics from 1974-1983 at Twin Lakes by Finnell (1983), Nesler (1981a), and Maiolie and Bergersen (1985) have demonstrated that there is a self-sustaining, fluctuating population with mean yearly densities that have ranged from 32-500 individuals/m^2. The disappearance of *Daphnia* spp. in Twin Lakes following the establishment of *Mysis* has been noted by LaBounty and Sartoris (1981).

Chalk Lake (Lake Co.)

Chalk Lake was sampled 11 years after introduction of *Mysis* and is the smallest lake observed to be maintaining a shrimp population. It is located on private property owned by AMAX Mining Corp., and is used for fishing for stocked rainbow trout. With the exception of an extensive mining operation located nearby, Chalk Lake appears similar to other alpine lakes in terms of limited drainage basin and good water clarity. Two benthic trawls were conducted by transporting the trawl by rubber raft toward the middle of the lake to the full length of 200 ft of rope. The trawl was allowed to settle on the lake bottom, and retrieved to shore. A total of 116 shrimp were collected, resulting in a mean density of 0.20 shrimp/m^2. The samples contained no adult shrimp, and were divided nearly equally between males and females. These results suggest a self-sustaining, but very low-level, shrimp population. Fourteen amphipods were also collected in the trawl.

One monofilament, experimental mesh gillnet was set overnight, resulting in a sample of six rainbow trout ranging in length from 178-200 mm. Stomach content observations of these fish showed only one fish had consumed 4-5 *Mysis*, with the others eating amphipods and smaller zooplankters. Two plankton hauls were made vertically through the water column, but no analyses have been performed as yet.

Clear Creek Reservoir (Chaffee Co.)

This reservoir has been drawn down completely several times since the introductory plants of *Mysis* in 1971. No shrimp were observed during June-July sampling in 1978. The basin remained empty overwinter in 1978-1979. It is highly doubtful that *Mysis* survived in this reservoir.

Crystal Pond (Lake Co.)

Another small, shallow water, Crystal Pond becomes heavily overgrown with aquatic plants by midsummer, and is probably subject to sharp diurnal fluctuations in dissolved oxygen content as well as periodic winterkill. Limited sampling with a benthic trawl revealed no Mysis shrimp, but the heavy plant growth may have interfered with the capture efficiency of the trawl. Trout of several species are stocked frequently. During the October 7, 1983 sampling effort, a fair number of larger dead trout were observed on the shallower areas of the lake bottom. No zooplankton samples were taken. One monofilament experimental mesh gillnet was set for 3 3/4 hours during midday and captured 21 rainbow trout ranging in length from 230-330 mm, 4 brown trout ranging in length from 177-240 mm, and one cutthroat trout that was 124 mm in length. Stomach contents of these fish included snails, odonate nymphs, corixids and some zooplankters, but no Mysis were present.

Jefferson Lake (Park Co.)

No Mysis were collected in this lake in 1976, 4 years after introduction; but in 1983, 11 years after introduction, establishment of a shrimp population was verified. Two benthic trawls were conducted for 2 minutes apiece on October 5, 1983, resulting in 80 and 700 Mysis shrimp. The smaller sample was comprised of 84% juveniles and 8% each of male and female immature yearling shrimp. The larger sample contained 40% juveniles, 32% immature males, and 28% immature females. No adult shrimp were collected. The benthic trawls were made at a slow, but undetermined boat speed using a 12-ft aluminum boat and 25-hp outboard motor. Assuming an approximate boat speed of 0.5 m/sec and a 60-m distance trawled, mean shrimp density for the two samples taken from this lake would be in the range of 7-62 shrimp/m^2 when corrected for trawl efficiency.

Two monofilament, experimental mesh gillnets were set for a 22-hour period, and captured 24 lake trout, one rainbow trout and one longnose sucker. The lake trout ranged in length from 282-523 mm. Twenty-three of the lake trout stomachs contained large numbers of Mysis. Scale samples were collected from the lake trout, and two vertical plankton hauls were made, but have yet to be processed. These results indicate a self-sustaining, moderate to abundant shrimp population that is utilized by the lake trout population.

Horsetooth Reservoir (Larimer Co.)

Horsetooth is the only coolwater reservoir to specifically receive introductory plants of Mysis shrimp. Like the other Front Range reservoirs included in the Colorado-Big Thompson Water Project, Horsetooth may have ultimately received Mysis via diversions from Grand Lake. Regardless of the method of introduction, Mysis appeared to have established itself in the reservoir by 1981. Benthic trawls conducted in separate locations in the reservoir resulted in low shrimp densities of 1.2-2.3 shrimp/m^2 (Nelson, unpublished data).

A recently completed study by Jones (1985) at Horsetooth indicated utilization of *Mysis* by walleye and rainbow smelt and no utilization by smallmouth bass. Specifically, walleye in the 100-299-mm size range and adult rainbow smelt at least 99 mm long appeared to show a preference for *Mysis*. The greatest utilization of the shrimp by smelt occurred in the autumn. These results suggest a function of reservoir habitat overlap between smaller walleye, adult smelt, and *Mysis*, as well as prey size selectivity and seasonal utilization. The interdependence of a *Mysis*-smelt-walleye food chain could have important implications for an enhanced walleye sport fishery at Horsetooth.

Mary, Carter and Estes Lakes (Larimer Co.)

These reservoirs all receive intermountain diversions from Grand Lake or Granby Reservoir as part of the Colorado-Big Thompson Project. Low-level populations of *Mysis* were confirmed by Nelson (unpublished data) in Carter Lake and Lake Estes in 1981, and again in Carter Lake in 1982. Carter Lake and Horsetooth are the only coolwater reservoirs in Colorado that contain *Mysis* shrimp. *Mysis* were observed in the shallow waters of Mary Lake near the diversion portal in 1984 during an extensive drawdown period for dam repair. Fishermen have reported *Mysis* in the stomachs of lake trout (also introduced via pipeline) in Mary Lake.

Grand Lake, Shadow Mountain Reservoir (Grand Co.)

Grand Lake has contained a relatively abundant population of *Mysis* shrimp since 1975, 4 years after introduction. Further sampling in Grand Lake from 1978-1980 (Nelson 1981), and from 1981-1983 (Nelson, unpublished data) indicates *Mysis* are maintaining an abundant population. Nelson (1981) indicated a noticeable decline in *Daphnia* populations in Grand Lake from a relatively abundant level in 1963-65 and 1971-75, to scarce or absent in 1978-80, and implicated *Mysis* as the causative factor.

Shadow Mountain Reservoir received *Mysis* shrimp via downstream importation from Grand Lake and/or pumping from Granby. This importation will probably be a continuous process due to very close proximity of the two lakes, so it would be difficult to determine if *Mysis* exist as an independent population in Shadow Mountain without extensive study. *Mysis* were sampled in Shadow Mountain in 1980 by Nelson (1981), and described as moderately to very abundant. *Mysis* were again sampled in Shadow Mountain in 1981. Nelson (1981) determined *Daphnia* sp. present in Shadow Mountain in November 1980 in small numbers.

Ruedi Reservoir (Eagle Co.)

Mysis shrimp were not evident in Ruedi during 1976-1978 from Clarke-Bumpus sampling, benthic trawls, Ekman dredge samples and fish stomach checks. In September 1983, 13 years after introduction, two of three benthic trawls in water depths of at least 32 m collected 14 and 1,046 shrimp. This equates to adjusted shrimp densities of 1-71/m^2. Fish sampled in September 1983 showed 4 of 19 brown trout had ingested *Mysis*. These fish ranged in length from 27-33 cm total length. Two of the browns were caught in a surface net set over 11-m water depth, and the other two browns were taken in a bottom net set at 3-9 m. Twenty-nine kokanee salmon were captured, none of which contained *Mysis*. Twenty-six of the salmon were taken in surface nets. Only two rainbow (27 and 31 cm) were taken (surface net), neither of which ingested *Mysis*. One lake trout (51 cm) was taken in a bottom net set at 9-15 m depths, and showed no evidence of ingested *Mysis*.

Zooplankton samples collected during July, August and September in 1978 showed *Daphnia* spp. constituted 9, 45, and 36% respectively of the zooplankton density in Ruedi (Nesler 1979). Zooplankton samples and fish scale samples were also taken at Ruedi in 1983 but have yet to be processed.

Taylor Reservoir (Gunnison Co.)

Mysis were first collected in Taylor in 1981, 7 years after introduction. One of two benthic trawl samples yielded 12 shrimp, suggesting a very low level population. Midwater trawl sampling with a 1-m Tucker trawl at various depths during the day and night resulted in no *Mysis* collected during the same year (Weiler 1982).

Job 2: To determine if changes have occurred in cladoceran species composition overall, and during each of the three seasonal thermal cycles: spring turnover, summer stratification, fall turnover, in the presence of *Mysis* populations.

RESULTS

The primary objective of this job was to quantify cladoceran and mysid abundance in four selected reservoirs—Dillon, Granby, Turquoise, and Green Mountain—and statistically analyze the results for an inverse relationship either over time, depth or both. The standardized sampling design to meet this objective was established for the 1985 open-water season. Subsequently, changes in project assignment prior to the 1985 season prevented any of the field work described for Job 2 from being accomplished (see Study Narrative). The objectives, stated as two hypotheses in the Narrative, cannot be met here.

Some zooplankton depth-series sampling in these four reservoirs occurred in 1983-84, and will provide some preliminary data on zooplankton populations, but these samples have not been processed. The preserved samples will be stored until the opportunity arises to continue such work.

One of the hypotheses within the Study Narrative to be tested stated:

> "Cladoceran species of zooplankton will coexist with *Mysis* shrimp populations if the temperature of the surface layer of the lake equals or exceeds 14 C, thereby limiting the diurnal migration of *Mysis*, and providing a refuge for cladocerans (i.e., *Daphnia* spp.) from *Mysis* predation."

This hypothesis was developed from work done by Rieman and Falter (1981) and Martinez (unpubl. M.S. Thesis, Colorado Coop. Fish Res. Unit). These studies and others by Beeton (1960), Teraguchi (1969), Brownell (1970), Gregg (1976), Bowers and Grossnickle (1978), and Morgan et al. (1978) indicated *Mysis* were restricted from surface waters in late summer due to high, unfavorable water temperatures. Gregg (1976) demonstrated adult *Mysis* were most affected by temperature. These studies support the validity of the refuge hypothesis. Martinez proposed 14 C as the temperature delimiting the lower depth boundary of this refuge. Data on cladoceran and *Mysis* densities to test this hypothesis are lacking but some depth profile-temperature data is available to compare the size and time dimensions of this potential refuge with historical zooplankton/*Mysis* abundance data on a few reservoirs. The Figures constructed for the lakes below depict the lower boundary of the potential thermal refuge using the 14 C isotherm. Approximate reservoir volume at selected depths are also depicted.

Twin Lakes

Based on an abundance of data collected from 1974-79 (Keefe 1980), the temperature profiles for these lakes (Fig. 1) suggest approximately a 72-day and 46-day period of existence for the thermal refuge in the lower and upper lake, respectively. The refuge occupies as much as 37% of the lower lake volume and only 12% of the upper lake volume. Under these environmental conditions, Daphnia spp. have failed to maintain a population in conjunction with an abundant Mysis population as indicated earlier (LaBounty and Sartoris 1981).

Grand Lake

Four years of temperature data (1971, 1972, 1975, 1981) (Nelson, unpublished) suggests an approximate 50-day life of a thermal refuge that does not even extend to 22% of the lake volume, and in some years is considerably less (Fig. 2). Mysis appeared to establish a population relatively fast (4 yrs) and are still maintaining an abundant level since 1975. The decline and disappearance of Daphnia in Grand Lake has been noted by Nelson (1981) since 1975.

Lake Dillon

Temperature data here suggests the thermal refuge for cladocerans ranged from 53 days in 1975 to 79 days in 1984 with an average of 66 days (1975, 1982, 1983, 1984 data) (Fig. 3). The refuge zone occupied between 17% and 36% of the reservoir volume most years (1975, 1980, 1982, 1983) but in 1978, 1981, and 1984 included between 33% and 44% of the reservoir volume. Data collected in 1979 indicates a thermal refuge didn't even develop by the end of August. According to Nelson (1981), Daphnia were relatively abundant in 1974-75 in Dillon but were notably scarce or absent in 1978-80. Daphnia sp remained scarce in 1982 (Nelson, unpublished) and also appeared scarce in 1984. Mysis were not sampled in 1977-78 in Dillon during graduate studies, but appeared abundant in benthic trawls during the 1981-1984 period with individual samples ranging from 2-284 shrimp/m^2 (Table 2).

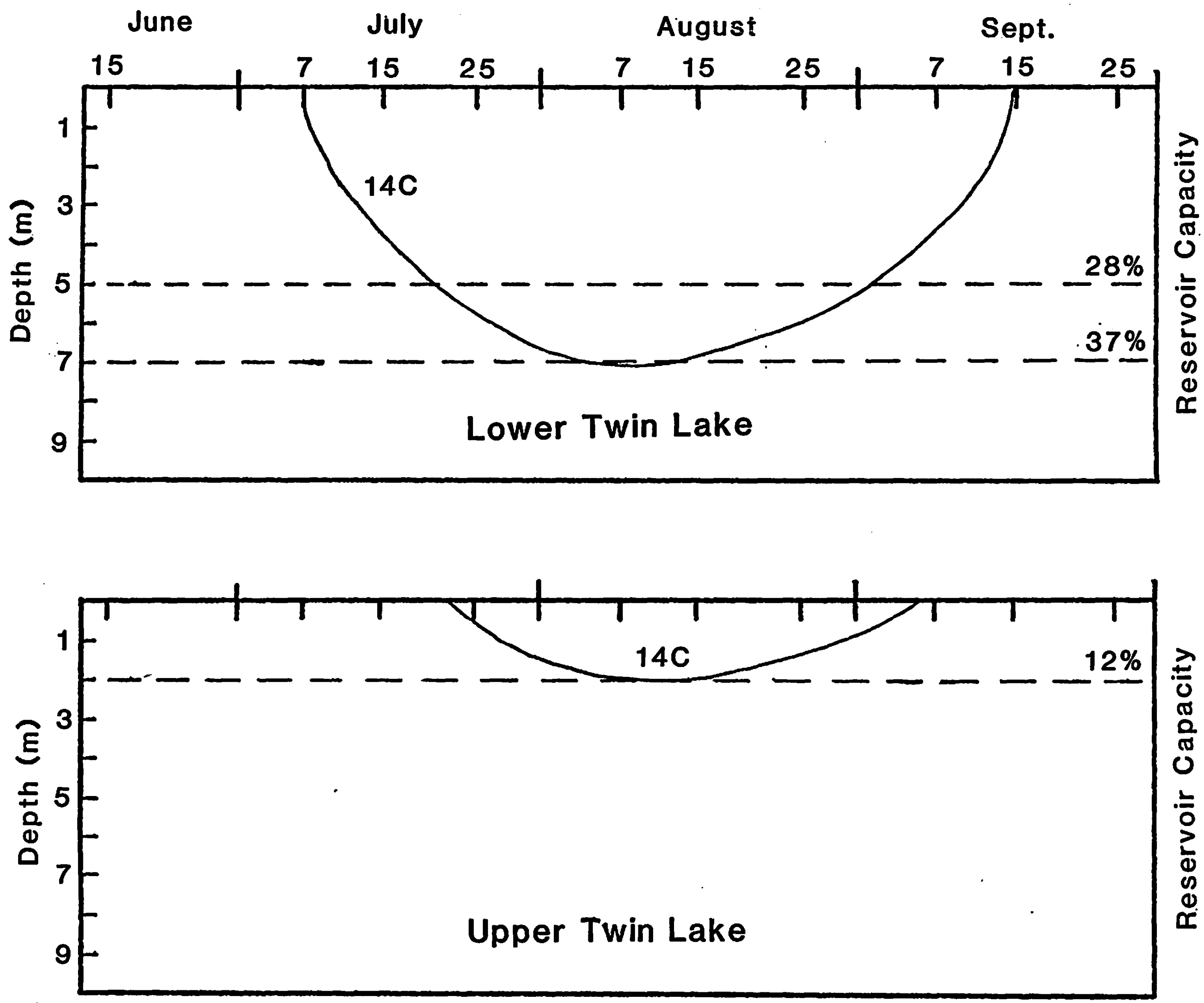


Figure 1. Potential thermal refuge for cladocerans to escape <u>Mysis</u> predation in Twin Lakes. 14 C isotherm established by 1974-1979 data base.

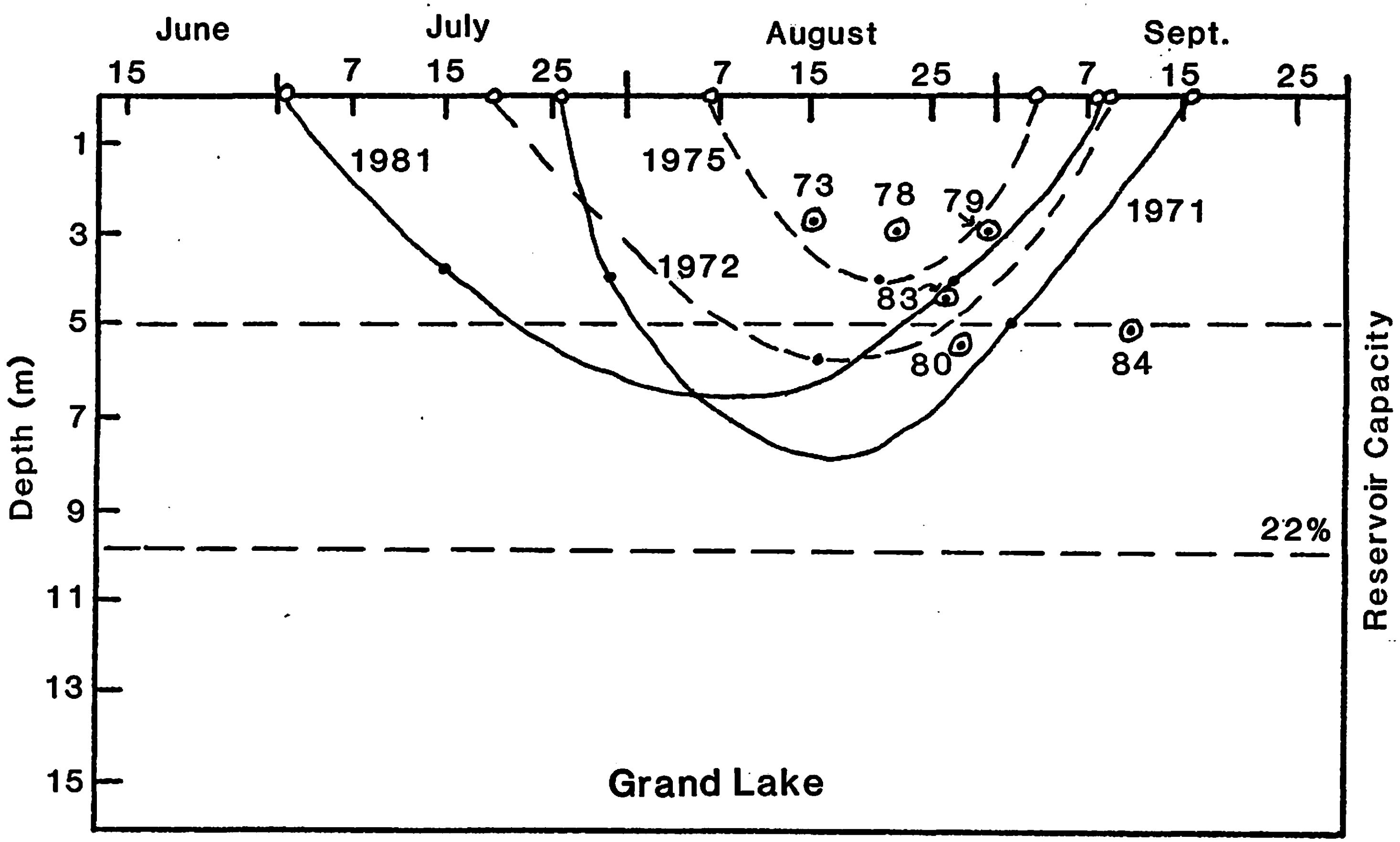


Figure 2. Potential thermal refuge for cladocerans to escape Mysis predation in Grand Lake. Years with only one temperature-depth profile depicted as circled dot signifying depth of 14 C water (e.g. 73⊙, 78⊙, etc.). Years with two or more profiles depicted with extrapolated curve of 14 C isotherm. Open circles on calendar axis represent estimated dates for beginning or ending of 14 C temperature water in given reservoir.

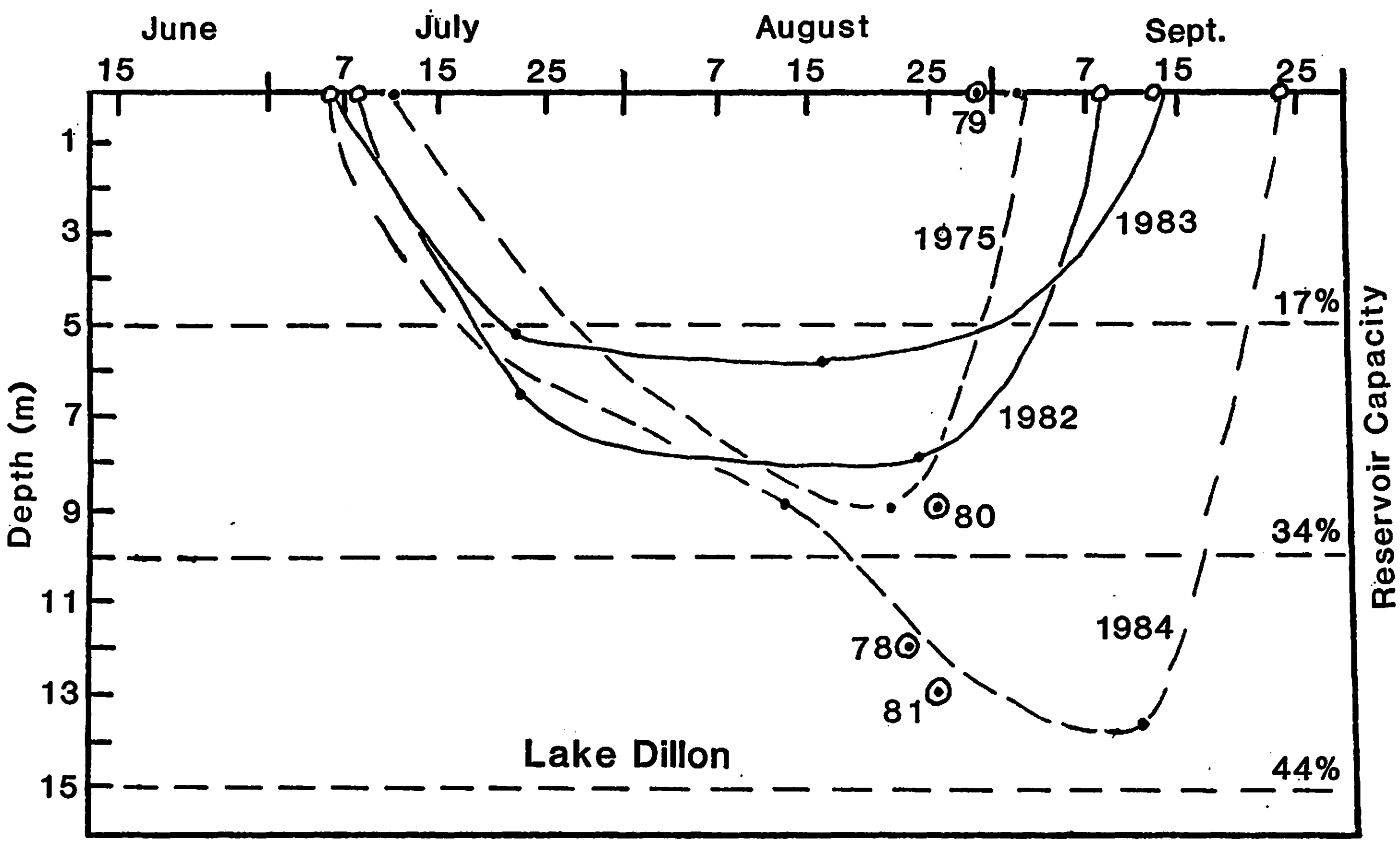


Figure 3. Potential thermal refuge for cladocerans to escape *Mysis* predation in Lake Dillon. See Figure 2 for detail explanation.

Table 2. Numbers of *Mysis* sampled in Dillon Reservoir, 1981-1984.

Date	Location	No. *Mysis* (/m^2)
8/81[a]	Main Lake	5,614 (223)
	Crown Point	11,309 (284)
6/82[a]	Main Lake	882 (44)
	Crown Point	2,554 (55)
	Frisco Bay	4,108 (103)
7/82[a]	Main Lake	804 (25)
	Crown Point	2,131 (55)
	Dollar Island	7,246 (170)
8/82[a]	Main Lake	252 (6)
	Sapphire Point	4,594 (94)
	Giberson Bay	4,792 (120)
9/82[a]	Dillon Overlook	1,563 (37)
	Main Lake	165 (4)
	Snake River Arm	958 (26)
11/82[a]	Main Lake	923 (23)
	Windy Point	6,642 (167)
	Sapphire Point	1,174 (29)
	Frisco Bay	1,191 (64)
8/83	Crown Point	2,759 (106)
	Giberson Bay	2,434 (150)
9/84	Main Lake	600 (22)
	Blue River Arm	468 (17)
	Snake River Arm	496 (18)

[a](Nelson, unpublished)

Green Mountain Reservoir

Limited temperature data indicates the thermal refuge existed for 89 days in 1982 (Nelson unpublished data)(Fig. 4). Single profiles for 1978 through 1983 (1982 inclusive) indicates the refuge occupies over 68% of the reservoir volume. In 1984 the percent volume occupied was approximately 58%. Sampling shows cladocerans maintained abundant populations in 1978-80 (Nelson 1981) as well as in recent years. Few (4-5) Mysis were sampled in 1979-80, 30-49 in 1981, 1-9 in 1982 (Nelson, unpublished), and none in 1983-84.

Granby Reservoir

Temperature data shows the thermal refuge for cladocerans begins in mid-June and extends through September, in excess of a 107-day period (Fig. 5). Five of seven years' data suggests the refuge occupies greater than 48% of the reservoir volume. Nelson (1981) indicated Daphnia has been relatively abundant at all times sampled (1963-65, 1971-72, 1978-80) and Mysis were well established by 1978. Martinez (unpublished M.S. Thesis) has demonstrated the persistence of some Daphnia sp and decline of others during 1981-83 in Granby. He also indicated Mysis declined to migrate into the upper 10 m of the lake in August and September where water temperature exceeded 14 C during stratification. He hypothesized the continued coexistence of Daphnia and Mysis in Granby due to the thermal pattern exhibited, which excluded Mysis from the upper 10 m, thereby creating a refuge in which Daphnia could develop a relatively abundant population.

Turquoise Lake

Two years of temperature data in 1978 and 1980 show the thermal refuge existed for 37 and 66 days respectively (Fig. 6). In contrast, 1984 temperatures showed a much more developed refuge existing in mid-September. In all 3 years the refuge occupied between 30% and 55% of the reservoir volume. In 1978, Daphnia comprised up to 54% of the zooplankton, but no more than 8% in 1980 (Nesler 1979, 1981b). Mysis were first observed in 1983 (Table 3). Benthic trawl sampling suggested an expanding mysid population comprised mostly of juveniles with a clumped or patchy distribution.

Ruedi Reservoir

The thermal refuge for cladocerans in 1978 existed for approximately 90 days and occupied between 39% and 50% of the reservoir volume. In late September 1983 the thermal refuge occupied over 50% of the reservoir volume (Fig. 7).

Taylor Reservoir

Temperature data in 1981 indicates the thermal refuge was quite extensive, extending from early June to beyond September—a total of 122 days. The refuge also occupied over 75% of the reservoir volume (Fig. 8).

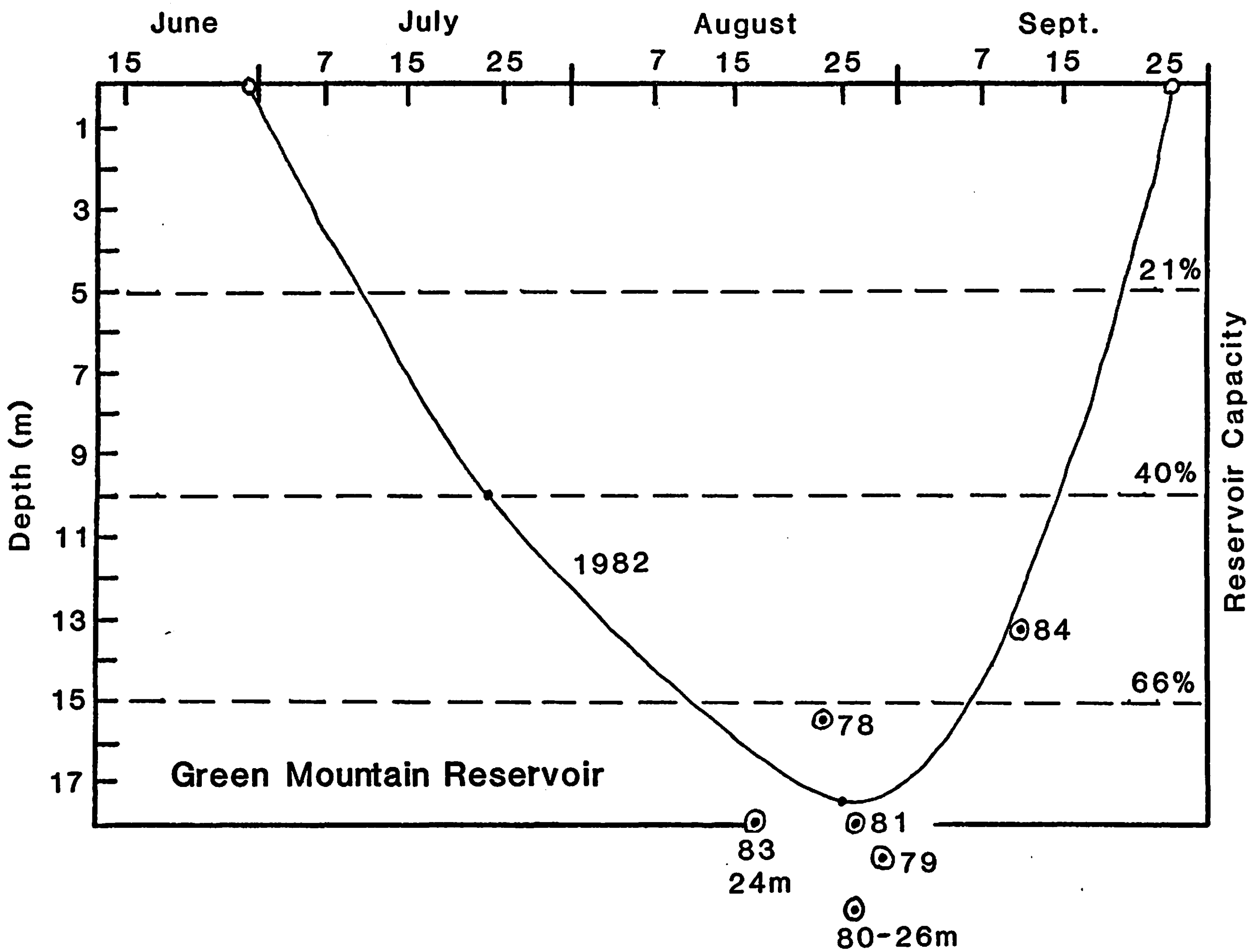


Figure 4. Potential thermal refuge for cladoceran to escape Mysis predation in Green Mountain Reservoir. See Figure 2 for detail explanation.

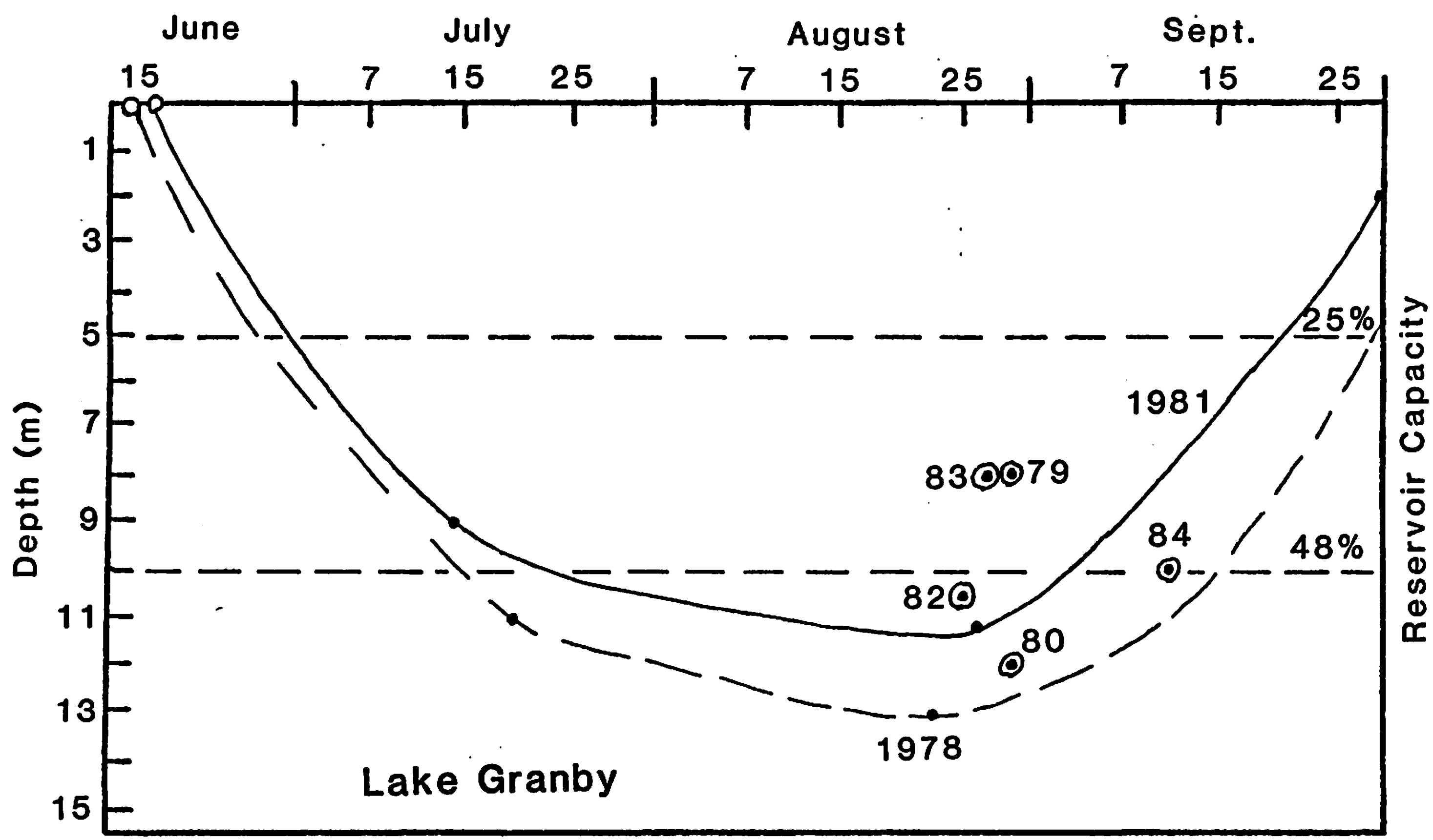


Figure 5. Potential thermal refuge for cladocerans to escape *Mysis* predation in Lake Granby. See Figure 2 for detail explanation.

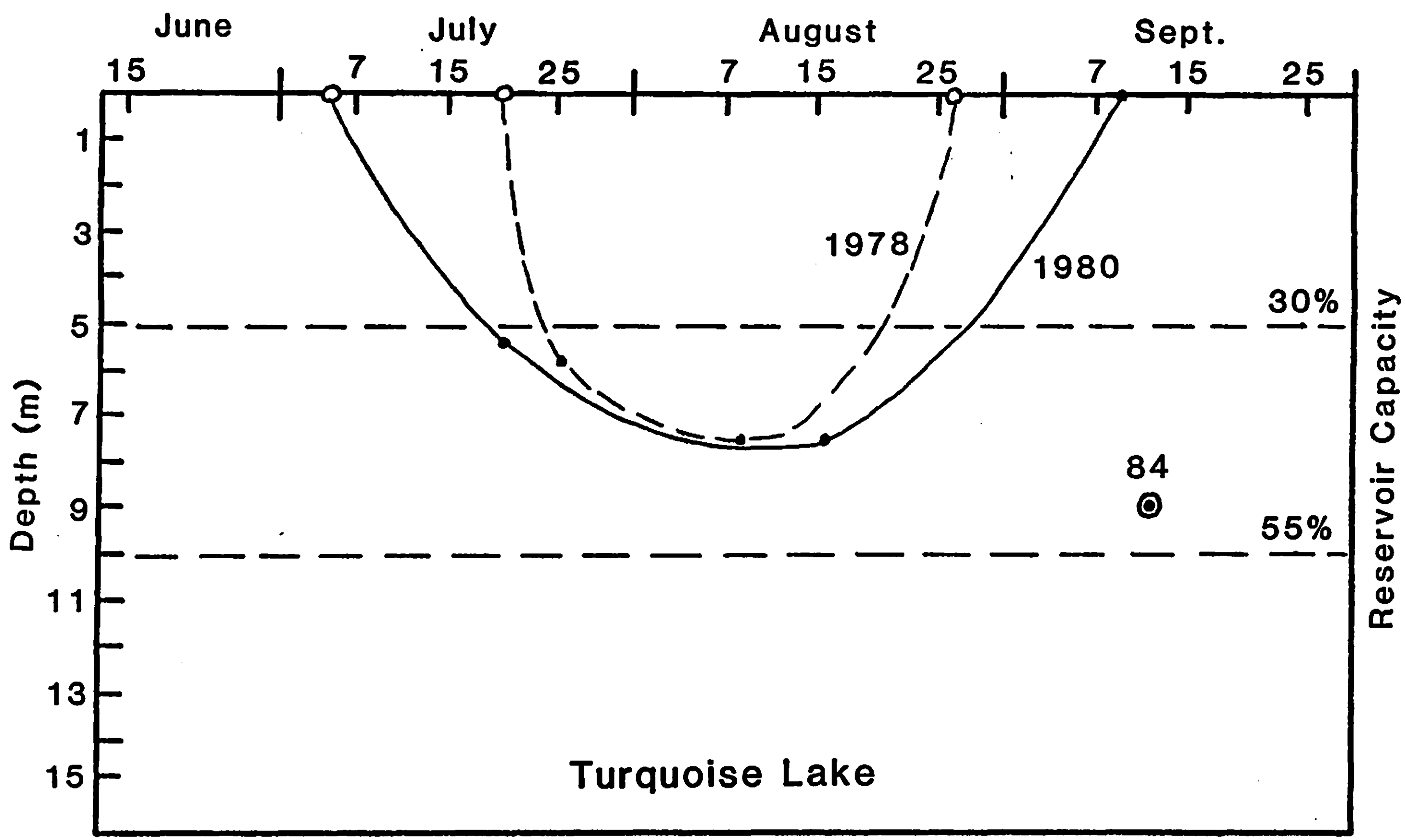


Figure 6. Potential thermal refuge for cladocerans to escape Mysis predation in Turquoise Lake. See Figure 2 for detail explanation.

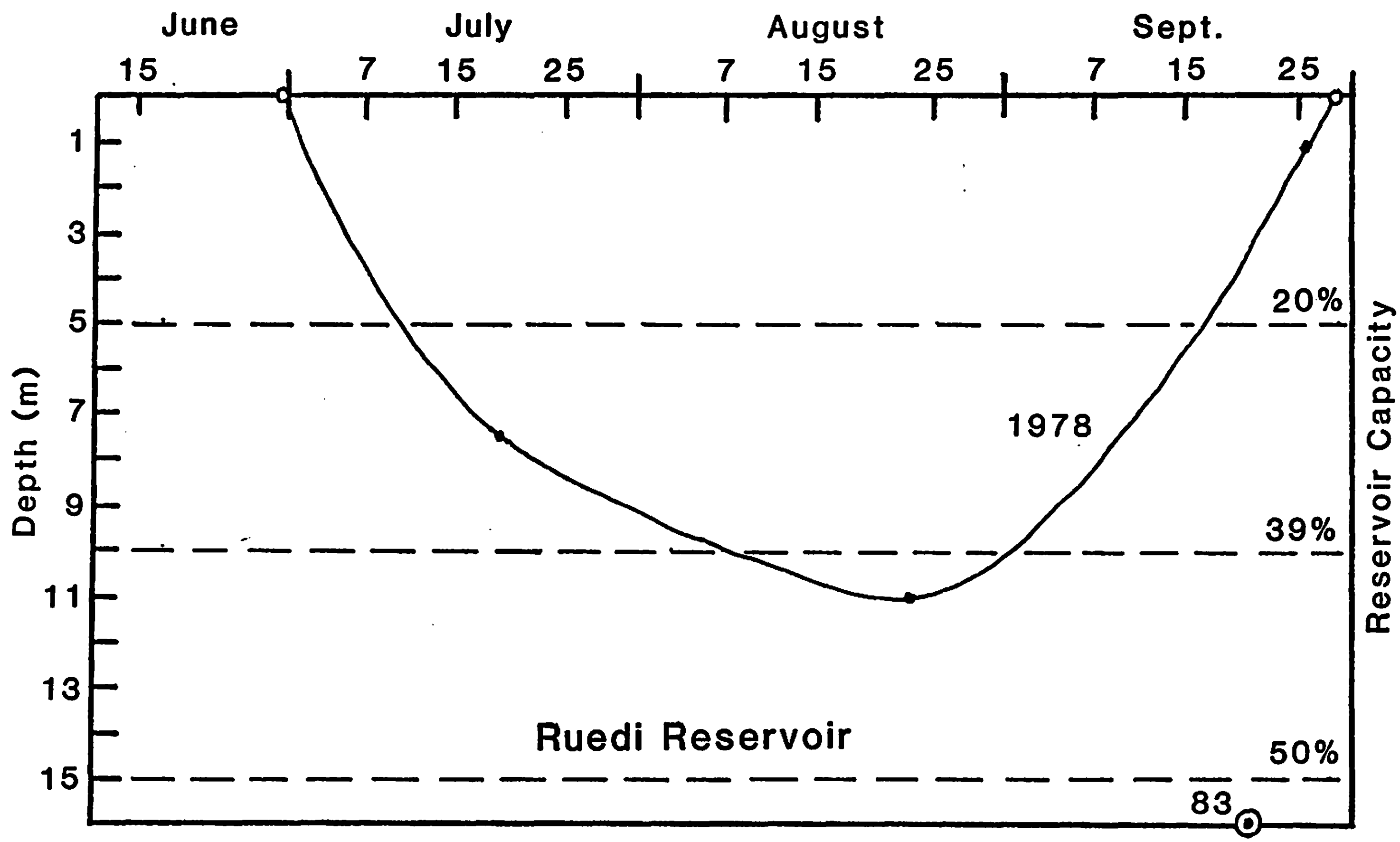


Figure 7. Potential thermal refuge for cladocerans to escape Mysis predation in Ruedi Reservoir. See Figure 2 for detail explanation.

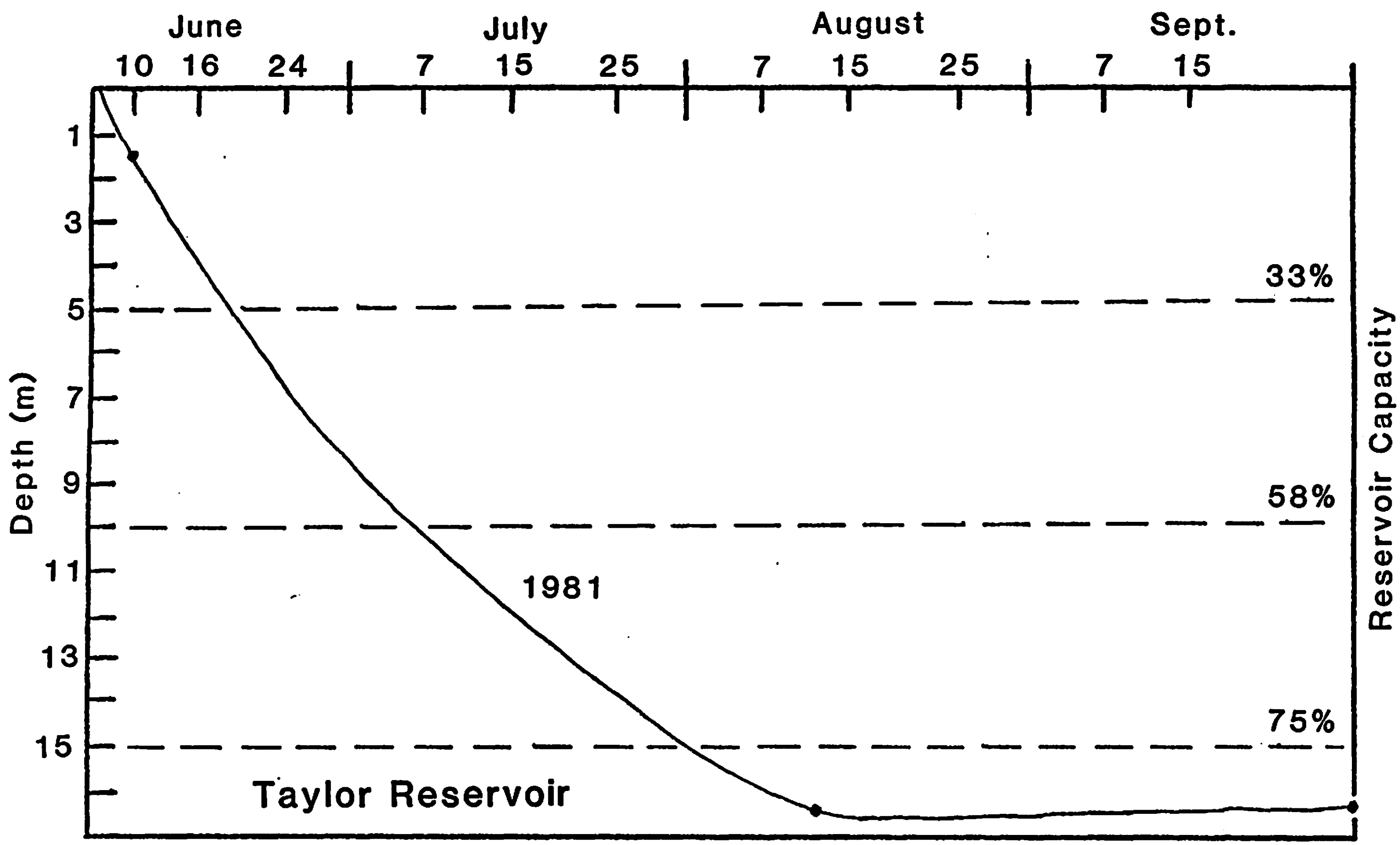


Figure 8. Potential thermal refuge for cladocerans to escape *Mysis* predation in Taylor Reservoir. See Figure 2 for detail explanation.

Table 3. Numbers of Mysis sampled in Turquoise Lake in 1983-84 using a benthic trawl (2-min sample).

Date	Location	Juvenile	Immature Male	Immature Female	Adult Male	Adult Female	Total
7/83	Dam	3			5[a]		8
	Midlake	27			8[a]		35
10/83[b]	Midlake	25	6	7		2	44
	Midlake	37	8	12	4	6	74
	Dam	129	24	40	13	13	219
	Dam	724	30	47	14	14	907
9/84[c]	Midlake						7[a]
	Midlake	136			46[a]		182
	Midlake	271			90[a]		361

[a]No age/sex differentiation made beyond separation of juveniles
[b]Two trawls in same location yielded no shrimp
[c]One trawl yielded no shrimp

Substudy Objective No. 2: To determine the effect of an established *Mysis* population upon the food habits, age and growth of salmonid populations in selected reservoirs.

Job 1: To determine if *Mysis* in Lake Dillon have changed the food habits, age structure or growth of kokanee salmon or brown trout, and evaluate the effectiveness of coho salmon as a *Mysis* predator and game fish.

RESULTS

Brown Trout

Samples of these trout were collected using both bottom and floating gillnets. Bottom gillnets were statewide standardized, coldwater, monofilament, 1.8 m depth by 38 m long with 19-44-mm experimental mesh. Floating gillnets were either 25- or 28-mm mesh multifilament nets that were 3.7 m deep by 30 m long. The sampling efforts in Lake Dillon were concentrated in the three major arms, with only two nets being set outside these areas (Fig. 9). Over the 1981-1984 period, 570 brown trout were captured, ranging in length from 152-670 mm. On a monthly basis, the numbers and type of gillnets set and the catch rate for brown trout varied considerably (Table 4). Sampling effort in 1981-1982 was minimal compared to 1983-84. Conversely, the brown trout catch rates observed in 1981-82 were among the highest recorded. The differences in relative abundance of brown trout suggested in Table 4 are probably more influenced by sampling variation and limited sample size rather than a significant decline in brown trout relative abundance. Results for 1983-84 were gained with more similar netting effort and thus may be more comparable.

Overall, 182 browns were captured in 1983 at a mean rate of 7.3/net, compared to 213 browns captured in 1984 at a rate of 7.9/net. Differences in catch rates between net types between years may be partly explained by average depths sampled. In all cases, nets of either type set in shallower water caught more browns. Bottom nets were set at a mean depth of 24 ft in 1983 and 40 ft in 1984. Floating nets, which sampled the upper 12-ft strata, were set over 36 ft of water on average in 1983, and over 23 ft of water on average in 1984. Two bottom nets were set in the main lake area at depths of 110 and 175 feet in 1984, and neither captured any fish.

Length frequency distributions of brown trout illustrate that 88-98% of the browns sampled were 40 cm or less in length (Fig. 10). Seven browns ranged in length from 51 to 67 cm in length and up to 3.6 kg in weight. The limited sampling efforts in 1981-82 resulted in roughly similar length frequency distributions. The more extensive netting effort in 1983-84 resulted in more captures of browns 25-32 cm in length, though potential sampling bias prevents the conclusion of a relative increase in this size group of trout over the 1981-84 period. Comparisons restricted to the 1983-1984 samples though, do suggest a large relative increase in brown trout from 21-30 cm in length, with only small numerical declines in the other three size groups in 1984 versus 1983. Scale samples were taken from most of the brown trout sampled in 1983-84, but analyses of age composition and growth will have to proceed at a later date.

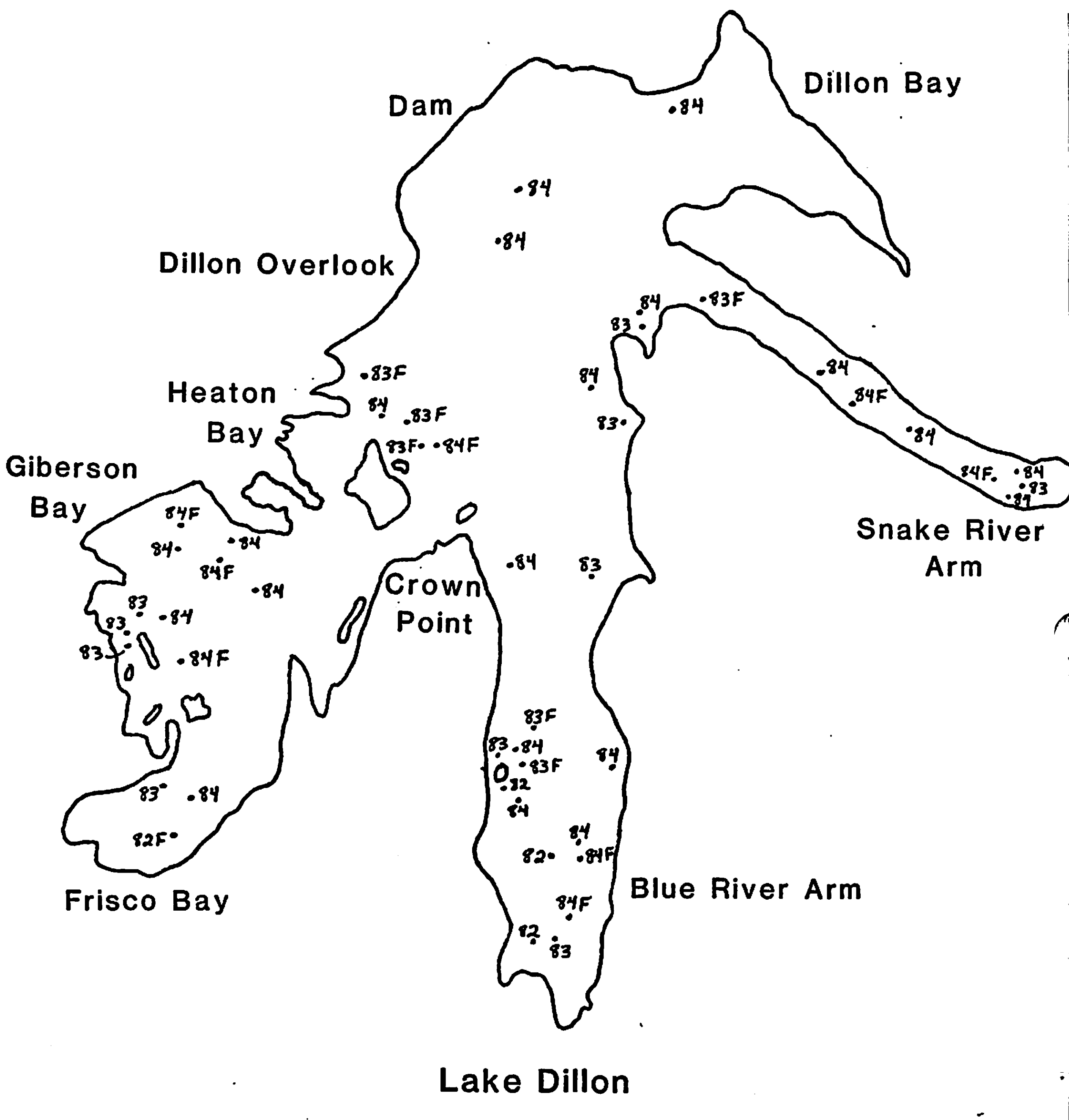


Figure 9. Gillnet sampling locations in lake Dillon from 1982-84. F=floating or midwater net set.

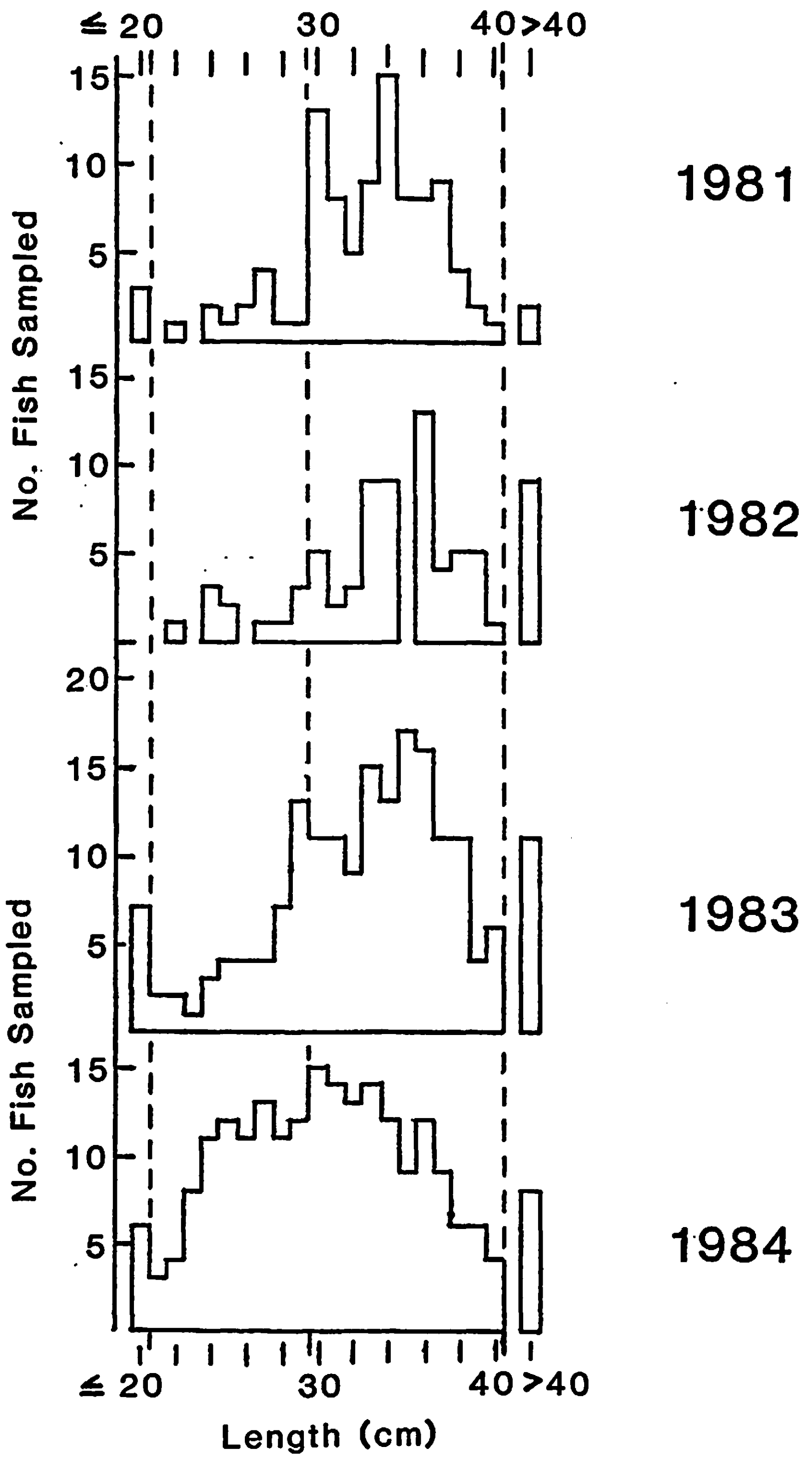


Figure 10. Length frequency distributions of brown trout sampled in Lake Dillon.

Table 4. Gillnet sampling effort and brown trout caught at Lake Dillon from 1981-84 according to month and net type.

Month	Year	Number nets set		Brown trout caught Total-X/net	
		Bottom	Floating	Bottom	Floating
July	1981	4	0	99-24.8	--
June	1982	3	1	63-21.0	13-13.0
June	1983	6	3	52- 8.7	15- 5.0
July	1983	3	4	25- 8.3	28- 7.0
August	1983	6	0	14- 2.3	--
October	1983	2	1	47-23.5	11.0
Total	1983	17	8	138- 8.1	44- 5.5
June	1984	9	4	48- 5.3	29- 7.3
July	1984	2	2	31-15.5	12- 6.0
September	1984	8	2	47- 5.9	46-23.0
Total	1984	19	8	126- 6.6	87-10.9

Kokanee-Coho Salmon

Relatively few kokanee salmon were collected in 1981 (9) an 1982 (5) due to the use of bottom net sets. The use of floating nets in 1983-84 significantly increased the sample size of kokanee. This included coho salmon sampled in 1984. A total of 155 kokanee and 53 coho salmon were collected by gillnets. Kokanee salmon ranged in length from 12-33 cm (Fig 11). At first glance, the length frequency distribution for kokanee suggests the presence of four age groups from 1+ at 12 cm, 2+ at 19 cm, 3+ at 25 cm, and perhaps 4+ over 30 cm. It is important to note that all kokanee presently in Lake Dillon are naturally spawned. By comparison, age 4+ kokanee at Granby Reservoir in 1985 were approximately 25 cm. Growth of these stocked kokanee has been significantly decreased in recent years (Wiltzius, per. comm.). It is therefore possible that up to five age groups may represent the observed length frequency distribution at Dillon. Scale samples of these fish have yet to be processed.

In contrast, all coho salmon sampled were known age 1+ fish. These salmon were stocked out in two different groups. A stock of larger coho was planted in Dillon the last week of September 1983 as age 0+ fish and a stock of smaller coho was made in mid-February 1984 as age 1+ fish. This disparity in fish sizes within the same year-class of fish would account for the range of lengths observed (18-31 cm)(Fig. 11). It is also likely that

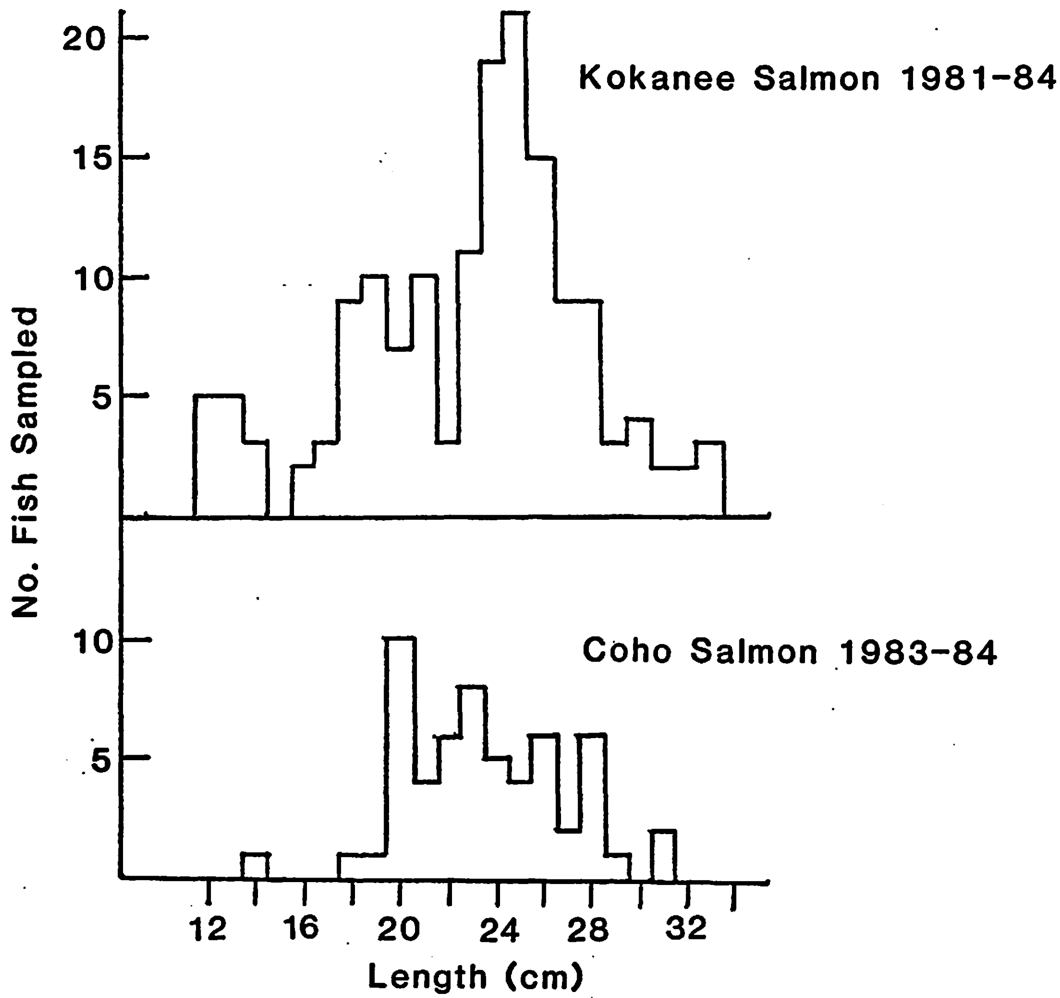


Figure 11. Length frequency distributions of kokanee and coho salmon sampled by gillnet in Lake Dillon.

age 1+ coho salmon in Dillon were much larger than their kokanee counterparts. Until growth rate analyses are conducted with existing scale samples, conclusions on the relative growth rates of the two salmon species cannot be made. It seems self-evident though that the hatchery-raised coho salmon may have greater growth potential than demonstrated by naturally spawned kokanee salmon using the current Lake Dillon forage base.

Other Fish Species

Other fish species collected by gillnets included rainbow trout, brook trout, white sucker and longnose sucker. Twenty-three rainbow trout ranged in length from 18-30 cm. Nineteen brook trout ranged in length from 18-36 cm. Ten of these brook trout were 30 cm and larger. Past experience suggests sucker populations are slowly increasing in Lake Dillon, because they were rarely caught in previous years. Through the 1981-84 period, 106 white suckers were collected, ranging from 16-44 cm in length, and 8 longnose suckers 21-33 cm in length were collected. Most of these suckers were collected in 1983 and 1984. Scale samples were collected from the salmonids but have not been processed.

Kokanee Salmon Population Sampling Via Midwater Trawls

The objective of midwater trawl sampling was to make a population estimate of fishes inhabiting the 0-60-ft stratum of Lake Dillon. This was in reference largely to salmon, though brown trout were occasionally captured as well. Trawl sampling efforts were conducted in July, September and October, 1983, and August 1984. Sampling was stratified by lake area and depth. Dillon was divided into four major areas—the main lake, the Snake River Arm, the Blue River Arm and the Ten Mile-Frisco-Giberson Bay area. In each area, replicate trawls were made at 0-20-, 20-40-, and 40-60-ft depth strata. In a given sample effort, 24 trawls were made over a 2-night period. The trawl mouth approximated a 20- x 20-ft square when open. Sampling at these desired strata were controlled by boat speed (0.5 m/sec) and the amount of warp released between the boat and otter boards. The amount of warp required for the three depth strata was 70, 110, and 180 ft.

Over the four trawl samples, a total of 249 kokanee salmon, 12 brown trout and 4 coho salmon were captured (Table 5). The catch data in Table 5 indicated a realistic population estimate was possible only for kokanee salmon. Examination of the length frequency distribution for kokanee captured in the trawl shows some distinct differences from the gillnet distribution (Fig. 12). Primarily, the presence of the large peak of age 0+ kokanee salmon at 3-5 cm in the trawl sample is obviously not included in the gillnet sample distribution. Thereafter the distributions become more similar, but multiple sampling dates over the summer growing season with each net type tends to blur any correlation of age groups represented. Kokanee gillnet samples were collected mostly in 1983-84 (see Table 4 for months sampled). The trawl sample results indicate the existence of 1-2 more age groups than the gillnet sample, and that perhaps the gillnet sample is represented by age 2+ to 5+ salmon. Scale samples of the salmon taken by the trawl were collected for later analysis.

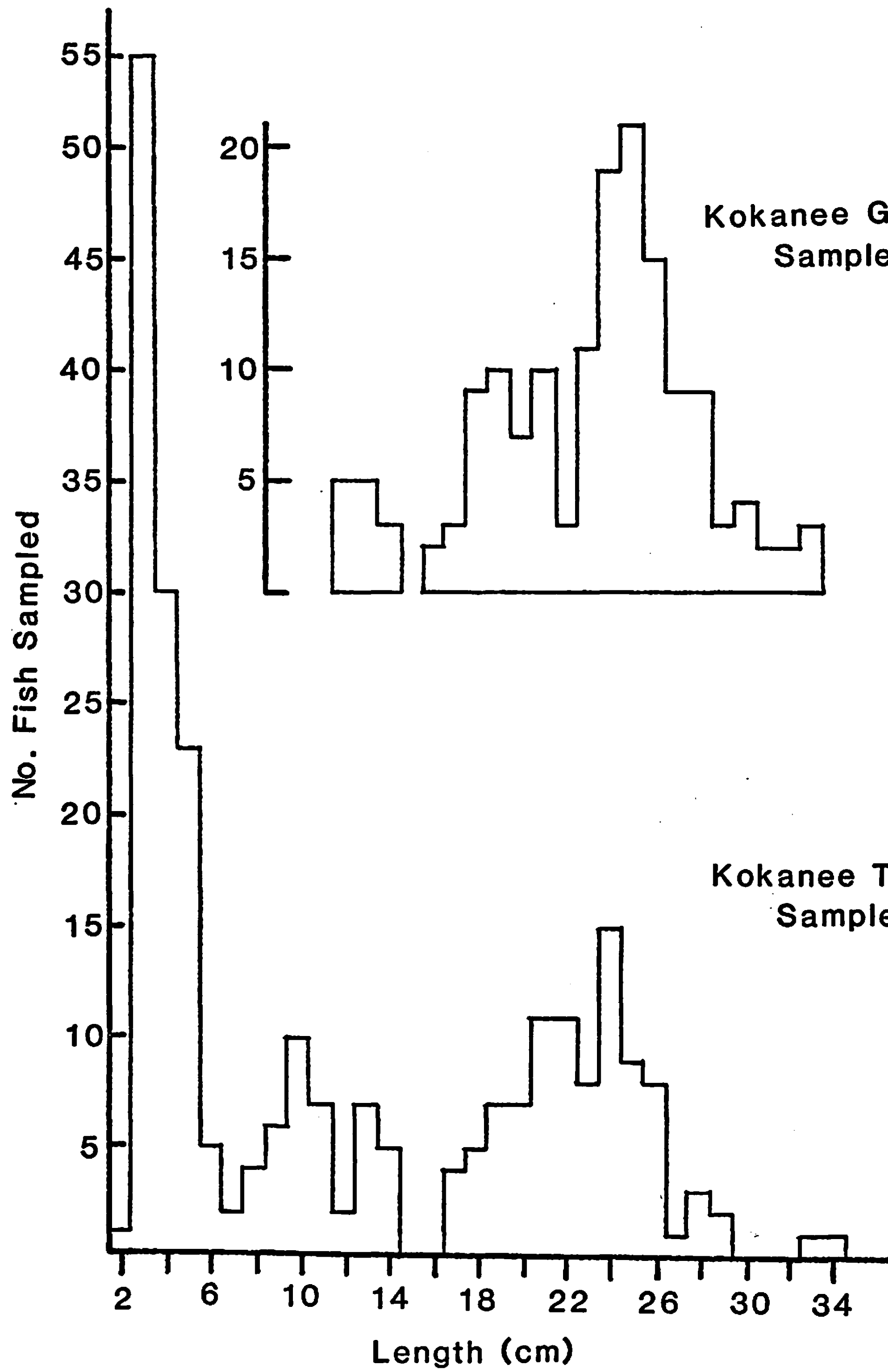


Figure 12. Comparison of length frequency distributions for kokanee salmon caught by gillnet and midwater trawl.

Table 5. Midwater trawl catch numbers by lake area, date, species, and depth stratum.

Lake Area Depth stratum (9ft)	Reservoir elevation (ft) 9,018.50 Date 7/21,25/83 Kok	 Brn	 9,012.89 9/14-15/83 Kok	 Brn	 9,013.09 10/18,19/83 Kok	 Brn	 Co	 9,010.36 8/22,23/84 Kok	 Brn	 Co
Snake River										
0-20	3	--	2	--	1	--	--	1	--	--
	5	--	0	--	0	--	--	0	--	--
20-40	2	--	2	--	0	--	--	1	--	--
	4	--	1	1	0	--	--	0	--	--
40-60	3	--	10	--				7	--	2
	2	--	6	--				3	--	0
Total	19	0	21	1	1	0	0	12	0	2
Blue River										
0-20	4	--	0	--	0	0	--	--	1	--
	4	--	0	--	0	0	--	--	1	--
20-40	1	--	1	--	1	1	--	2	1	--
	0	--	0	1	0	0	--	2	1	--
40-60	1	--	17	--	--	1	--	7	--	--
	1	--	10	--	1	--	--	0	--	--
Total	11	0	28	1	2	2	0	11	4	0
Mid Lake										
0-20	6	1	2	--	1	--	--	3	--	--
	2	0	0	--	0	--	--	2	--	--
20-40	4	--	1	--	0	--	--	3	--	--
	10	--	0	--	0	--	--	0	--	--
40-60	15	--	2	--	2	--	--	15	--	--
	11	--	2	--	5	--	--	11	--	1
Total	48	1	7	0	8	0	0	34	0	1
Tenmile										
0-20	0	--	1	--	--	--	1	--	--	--
	4	--	2	--	--	--	0	--	--	--
20-40	3	--	3	1	1	--	--	2	1	--
	8	--	1	--	0	--	--	0	0	--
40-60	9	--	1	--						
	5	--	7	1						
Total 29	29	0	15	2	1	0	1	2	1	0
GRAND TOTAL	107	1	71	4	12	2	1	59	5	3

The kokanee catch data in Table 5 were used in the formula provided below:

$$\text{Pop. Est.} = \frac{T_1 + T_2}{2} \times \frac{SV}{VS}$$

where:

T_1 = trawl sample #1
T_2 = trawl sample #2
SV = strata volume
VS = volume sampled by trawl net
= 9.04 ac-ft/10 min sampling time

to determine population estimates of salmon for a given lake area and stratum, and for the total reservoir within the 0-60-ft stratum. Strata volume was determined for the three depth strata sampled per lake area based on reservoir level at the sample time and capacity tables for Lake Dillon. The standard error of these estimates was calculated with the formula for estimated variance of the above population estimate and is given as:

$$\text{Var. (pop. est.)} = \sqrt{\frac{\frac{(T_1 - T_2)^2}{2} \times \left(\frac{SV}{VS}\right)^2}{2}}$$

The details of the development of the trawl technique for estimating population size, sample size and variances are provided in Babcock (unpublished).

Table 6 demonstrates that the total population estimates for kokanee declined by 89% between the July-October period in 1983. No distinct distributional pattern is evident, though the main lake area tended to hold the most salmon, and the 40-60-ft stratum in each lake area tended to contain the most salmon. The August 1984 estimate appears statistically similar to the September 1983 estimate. Coefficients of variation were quite small for the estimates in Table 6, ranging from 0-7%.

Brown Trout Spawning Population

Electrofishing of the three major tributaries to Lake Dillon was conducted periodically to determine the relative use of each by adult brown trout and the size frequency of the fish in the spawning run.

Table 6. Kokanee salmon population estimates by lake area, date and depth strata. Standard errors included in parentheses.

Date	Strata[a]	Section				Total
		Main L.	Snake R.	Tenmile	Blue R.	
July 21,25 1983	9018/8998	12,100(78)	2,200(24)	2,500(50)	6,700(0)	23,500(96)
	8998/8978	9,600(64)	2,600(30)	12,000(42)	400(19)	24,600(84)
	8978/8958	19,200(54)	300(8)	5,000(38)	1,700(0)	26,300(67)
	Total	40,900(114)	5,100(39)	19,500(76)	8,800(19)	74,400(144)
Sept 14-15 1983	9013/8993	2,700(52)	500(22)	2,500(29)	0(0)	5,700(63)
	8993/8973	600(24)	1,400(21)	3,400(41)	500(23)	5,900(57)
	8973/8953	2,600(0)	900(15)	3,100(48)	22,300(76)	28,900(91)
	Total	5,900(57)	2,800(34)	9,000(69)	22,800(79)	40,500(125)
Oct 18-19, 1983	9013/8993	1,400(5)	200(16)	0(0)	0(0)	1,600(17)
	8993/8973	0(0)	0(0)	900(29)	500(23)	1,400(37)
	8973/8953	4,600(44)	0(0)	0(0)	800(29)	5,400(53)
	Total	6,000(44)	200(16)	900(29)	1,400(37)	8,400(67)
Aug 22-23, 1984	9010/8990	6,400(36)	200(15)	0(0)	0(0)	6,700(39)
	8990/8970	1,500(39)	500(22)	1,400(38)	2,600(0)	6,000(59)
	8970/8950	15,600(49)	500(14)	0(0)	5,600(75)	21,800(91)
	Total	23,500(72)	1,200(30)	1,400(38)	8,200(75)	34,500(115)

[a]Given as reservoir surface elevations corresponding to 0-20-, 20-40-, and 40-60-ft depth strata.

Blue River

Five samples were collected here, covering a period from October 4 through November 29, 1984. On October 4 and 11, pocket sampling in pools, eddies and undercut banks was conducted from the inlet upstream 200 ft past the reservoir road bridge. The last three sampling efforts were conducted in a riffle-pool-riffle sequence several miles upstream near the former emergence site of the Blue River from under the placer mine tailings and Swan Creek confluence.

The early October samples at the lake inlet resulted in a large proportion of immature juvenile brown trout ranging from 9-27 cm total length (Fig. 13). Mature brown trout represented 41% of the two samples and ranged from 21-46 cm in length. As may be expected, the length frequency distribution of brown trout collected in the three sampling efforts further upstream in late October/early November demonstrated a much greater proportion of adult spawning brown trout. Here immature fish represented 18% of the samples and ranged from 12-28 cm in length. Adult browns ranged from 20-66 cm in length.

Later results will verify that the majority of brown trout spawners from Lake Dillon migrate up the Blue River. By the October 11 sample, all adult male brown trout were ripe; the females were green, except for one spent and one ripe female. Most brown trout collected of both sexes were ripe by the October 30-November 8 samples. By November 29, the relative abundance of adult fish was noticeably less and 81% of the females collected appeared spent. Only two brook trout and no kokanee or coho salmon were collected during the five sampling efforts.

Tenmile Creek

Sampling efforts were conducted from October 5 through November 29. On October 5 and 12, pocket sampling in pools, eddies, snags and undercut banks was conducted from the inlet upstream 200 ft past the Frisco highway bridge. The October 30 and November 8 and 29 sampling efforts were conducted at the fish ladder constructed at the Fourth Street bridge upstream in residential Frisco. A short series of large pipeline conduit has been used to construct a fish passage over a small overhead dam serving as the bridge foundation.

Both brown and brook trout spawners were evident with ripe males of both species and green female brown trout collected by October 12. Adult brown trout ranged from 20-61 cm total length (Fig. 14). Juvenile brown trout ranged from 12-22 cm in length. Brook trout spawners ranged from 14-31 cm in length. Both sexes of both species were ripe on the October 30/ November 8 sampling efforts. By November 29, the creek was heavily iced over and appeared totally blocked to fish passage by ice at the Fourth Street bridge. Only a few fish, with some ripe female trout, were collected. No kokanee or coho salmon were collected.

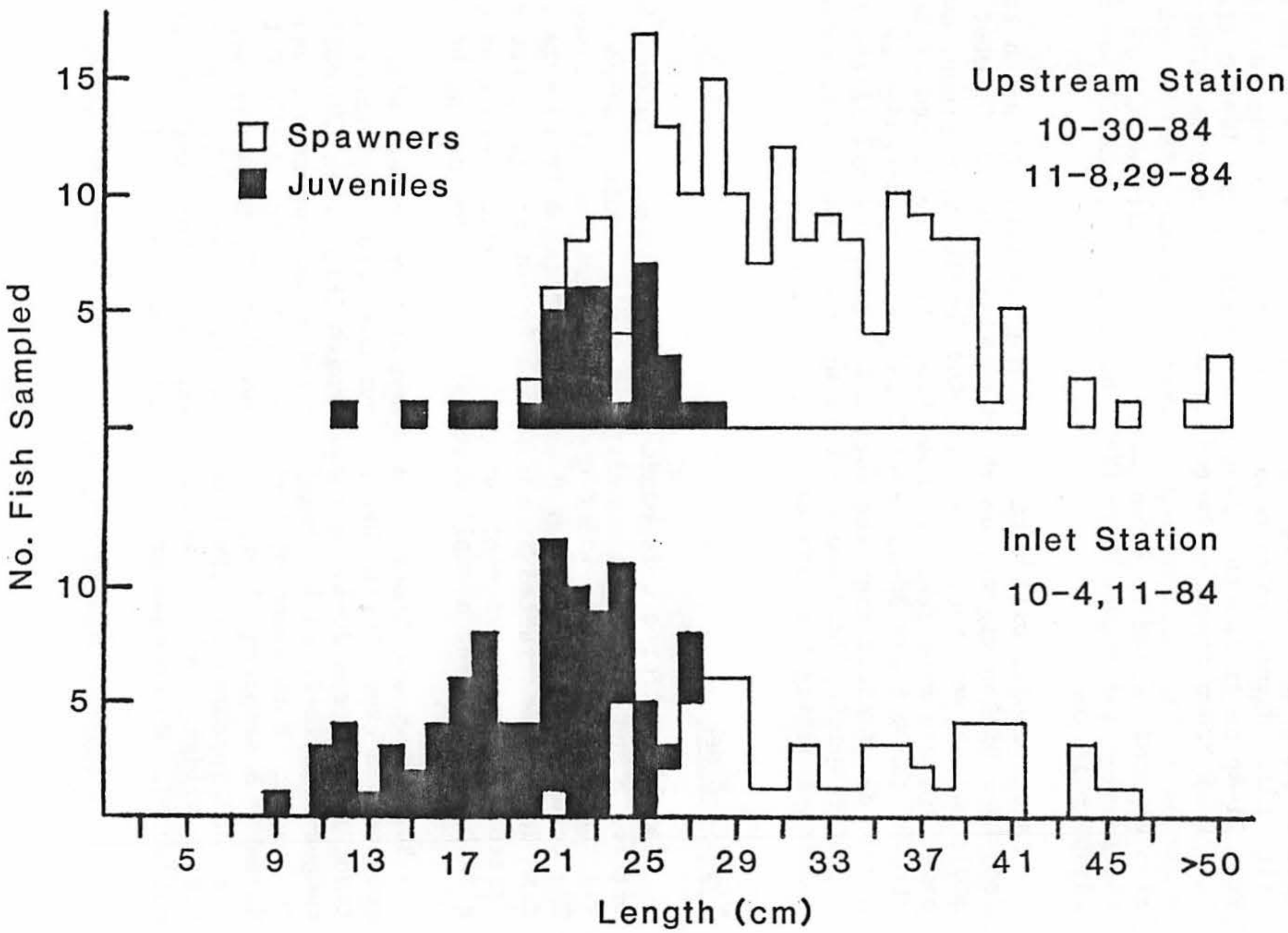


Figure 13. Length frequency distribution of juvenile and spawning brown trout at two stations in the Blue River, 1984.

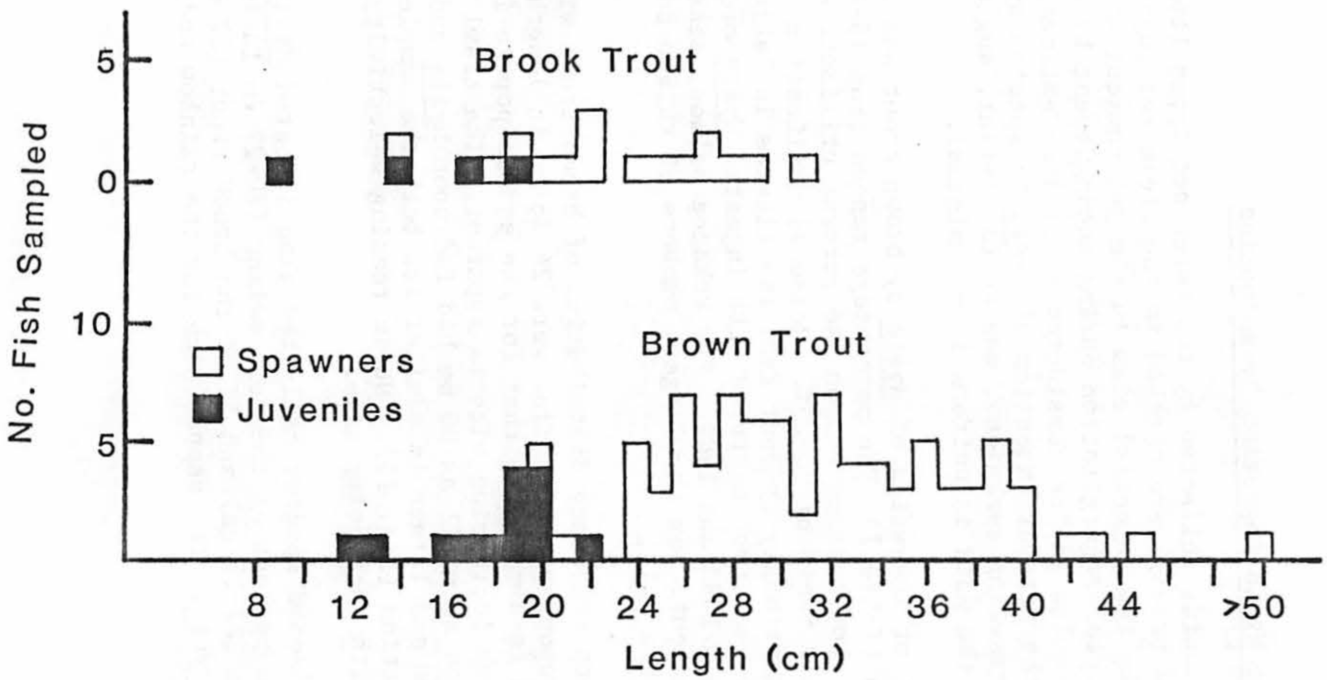


Figure 14. Length frequency distributions of brook and brown trout juveniles and spawners in Ten-Mile Creek, 1984.

Snake River

Very few fish were ever collected in this tributary, even though pocket sampling was conducted from the inlet upstream 300 ft past the highway bridge. In four sampling efforts, only 28 trout were collected--15 brown trout (12-37 cm total length), 12 brook trout (10-29 cm), and 1 rainbow trout (24 cm). Some ripe males and green females were noted within the brown and brook trout collected. By November 29, this tributary was heavily iced over and inaccessible to sampling. No salmon were ever sampled upstream, but many kokanee and a few coho salmon were being caught by anglers through the ice in the inlet bay on November 29.

Incidence of *Mysis* ingestion by salmonids

All salmonids collected by the three net types (bottom set, floating gillnets and trawl) were checked in the field for ingested *Mysis* shrimp. Acknowledging the potential bias in the gut content observations due to partial or total regurgitation during entanglement by gillnets, the following results may be considered as minimum estimates. With regard to this bias, the percent ingestion of *Mysis* by species and net type, including the active trawling technique, was quite similar, suggesting the impact of the bias to the data is uniform if not minimal.

The percent ingestion of *Mysis* by brown trout was 17% for the 582 total fish sampled (Table 7). The percentage ranged from 15-18% over the three net types used. For kokanee salmon the percent utilization was 22% for 289 fish sampled with a range of 20-25%. Seasonal utilization of *Mysis* by brown trout is not strongly evident from the figures in Table 7, but the largest numbers of brown trout captured with ingested *Mysis* occurred during the fall months in both 1983 and 1984. For kokanee salmon, seasonal utilization is also not clearcut, but the largest numbers of salmon containing *Mysis* also occurred in the fall.

The length frequency distribution of brown trout with ingested *Mysis* shows the preponderance of fish were 24-36 cm in length (Fig. 15). This distribution is similar to that for the sample population. No selectivity for *Mysis* with increasing size is apparent. The trawl sampling demonstrated kokanee salmon as small as 80 mm had fed upon *Mysis* and the distribution of salmon 180 mm and larger is similar for both the sample population and *Mysis*-eating population (Fig. 16). No increasing selectivity of salmon for *Mysis* is evident with increasing size.

Other salmonid species collected also ingested *Mysis* to a lesser degree. Nine percent of the coho salmon (20-27 cm in length), 9% of the rainbow trout (27-28 cm) and 5% of the brook trout (27 cm) showed evidence of ingested *Mysis*. The sample size for the rainbow and brook trout was quite small.

Table 7. Numbers and percent of brown trout and kokanee salmon captured by various net types with evidence of ingested *Mysis*.

Sample date (MMDDYY)	Brown Trout: Bottom gillnet No	%	Floating gillnet No	%	Trawl No	%	Total No	%	Kokanee Salmon: Bottom gillnet No	%	Floating gillnet No	%	Trawl No	%	Total No	%
061082	1	2	6	46	---	---	7	9	0	0	1	20	---	---	1	20
062283	10	19	5	33	---	---	15	22	2	29	10	100	---	---	12	71
070583	0	0	3	11	---	---	3	6	0	0	4	27	---	---	4	20
071583	0	0	0	0	---	---	0	0	2	50	3	43	---	---	5	45
072183	---	---	---	---	0	0	0	0	---	---	---	---	11	18	11	18
081783	7	50	---	---	---	---	7	50	0	0	---	---	---	---	0	0
091483	---	---	---	---	1	25	1	25	---	---	---	---	16	46	16	46
101883	27	57	0	0	0	0	27	56	1	25	3	43	2	20	6	29
061384	7	18	---	---	---	---	7	18	0	0	---	---	---	---	0	0
062884	1	10	6	21	---	---	7	18	0	0	0	0	---	---	0	0
071984	0	0	1	8	---	---	1	8	0	0	4	33	---	---	4	22
082284	---	---	---	---	1	20	1	20	---	---	---	---	0	0	0	0
092784	22	49	0	0	---	---	22	25	6	33	0	0	---	---	6	33
Total	75	18	21	15	2	17	98	17	11	20	25	25	29	22	65	22
N	426		144		12		582		55		100		134[a]		289	

[a]Includes kokanee salmon 80 mm and larger only

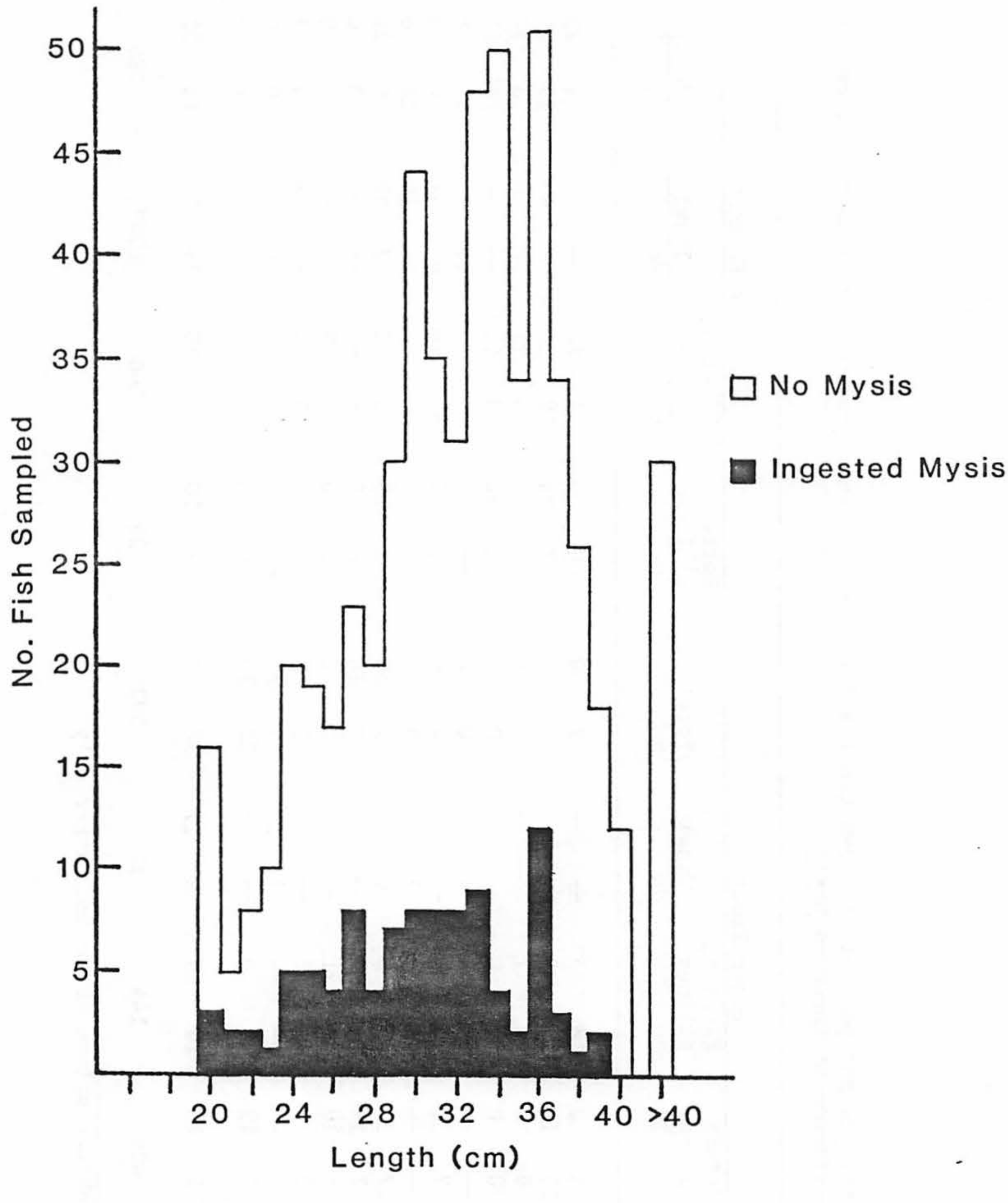


Figure 15. Comparison of length frequency distributions of brown trout with and without ingested Mysis shrimp in Lake Dillon.

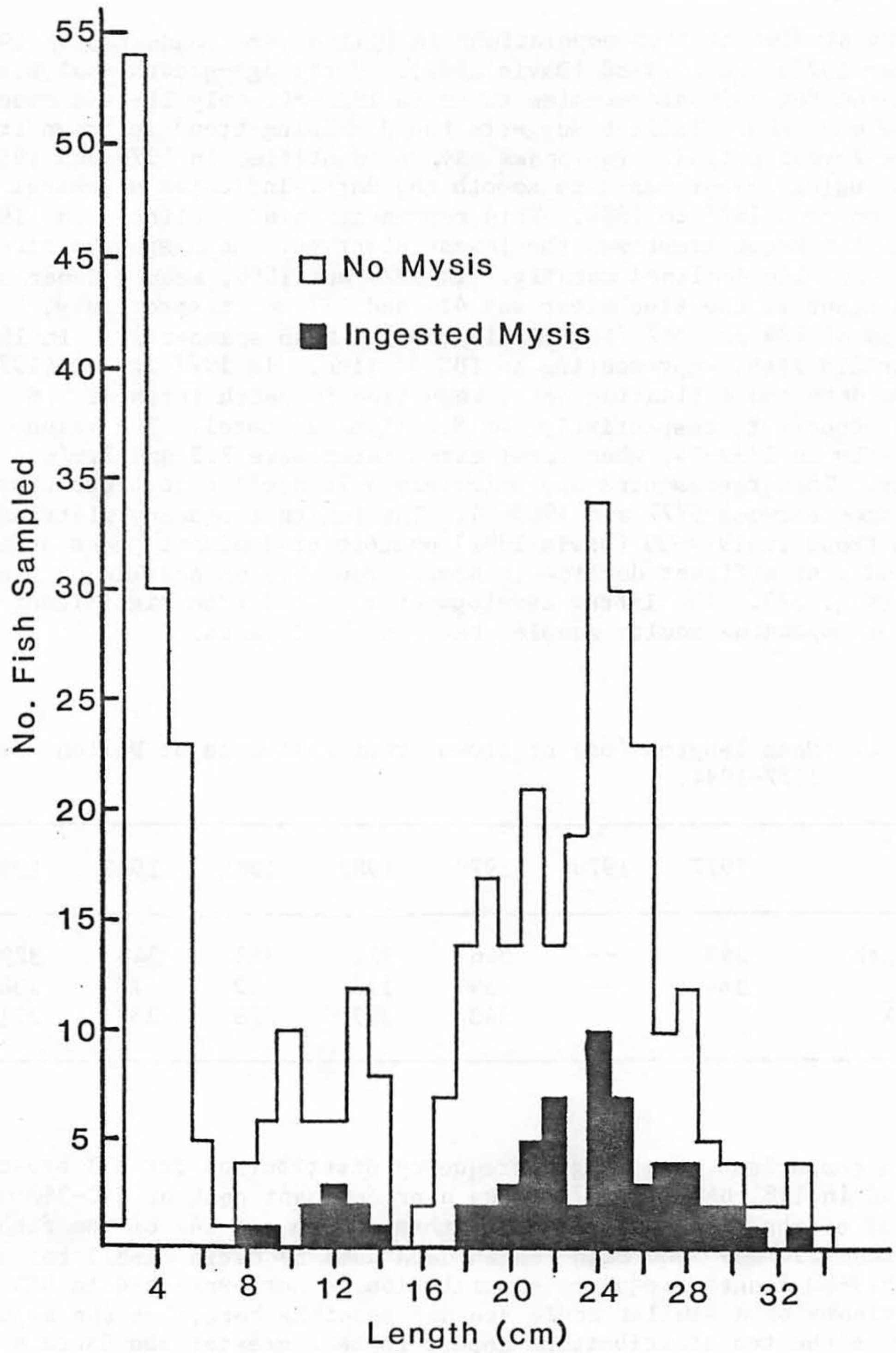


Figure 16. Comparison of length frequency distributions of kokanee salmon with and without ingested Mysis shrimp in Lake Dillon.

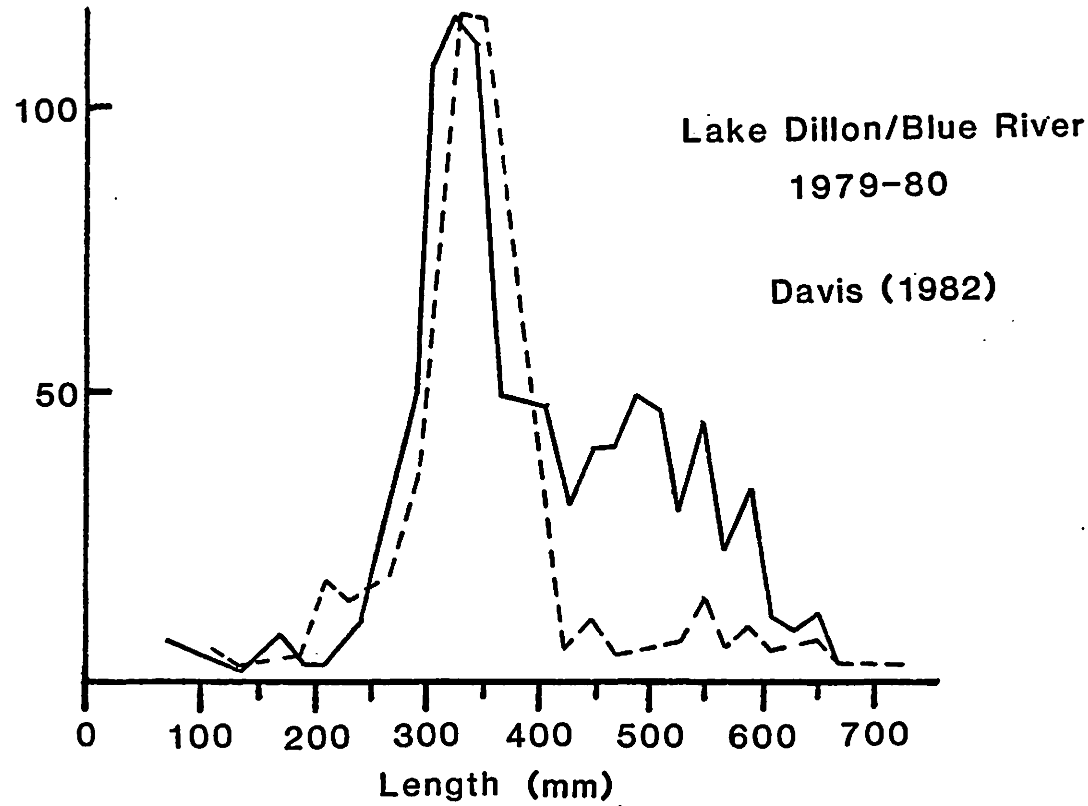
Fish Population Trends

Two studies of fish populations in Dillon were conducted in 1977-78 (Stuber 1979) and 1979-80 (Davis 1982). Until age-growth analysis are completed for salmonid samples taken in 1983-84, only limited comparisons can be made now. Table 8 suggests the declining trend in brown trout size over a 7-year period. Two peaks may be identified in 1979 and 1982, but the trend, using 3-year means to smooth the data, indicates a general decrease of 22 mm from 1977 to 1984. This represents a 6% decline. The 1984 mean length for brown trout was the lowest observed. Mean spawner size for brown trout has also declined notably. In 1979 and 1980, mean spawner size for brown trout in the Blue River was 414 and 377 mm, respectively, based on samples of 794 and 947 fish (Davis 1982). Mean spawner size in 1984 was 324 mm for 218 fish, representing an 18% decline. In 1977 Stuber (1979) set 14 bottom nets and 6 floating nets, resulting in catch rates of 9.6 and 5.0 brown trout/net, respectively, or 8.2 fish/net total. The values compare favorably to 1983-84, when total catch rates were 7.3 and 7.9/net respectively. This represented approximately a 7% decline in brown trout relative abundance between 1977 and 1983-84. The length frequency distributions for brown trout in 1979-80 (Davis 1982) exhibit predominant peaks at about 330 mm, and a significant decline in brown trout 425 mm and larger from 1979 to 1980 (Fig. 17). The latter development resulted from significant differences in spawning adults sampled between the 2 years.

Table 8. Mean lengths (mm) of brown trout collected at Dillon Reservoir, 1977-1984.

	1977	1978	1979	1980	1981	1982	1983	1984
$\bar{X}$ length	343	--	366	321	328	345	329	306
N	164	--	159	176	99	76	188	218
3 yr $\bar{X}$			343	339	328	332	321	

In comparison, the length frequency distribution for all brown trout sampled in 1981-84 (Fig. 17) shows a predominant peak at 340-360 mm with only 5% of the fish sampled larger than 400 mm and 24% of the fish sampled less than 250 mm. The fish length data used by Davis (1982) to construct the 1979-80 length frequency distribution is not presented in his report, so comparisons on a similar scale are not possible here, but the major differences in the two distributions appear to be a greater abundance of smaller brown trout less than 300 mm in length in 1981-84, due largely to 1983-84 samples, and a considerable decrease in the numbers of larger brown trout greater than 400 mm in length from 1977-80 to 1981-84.



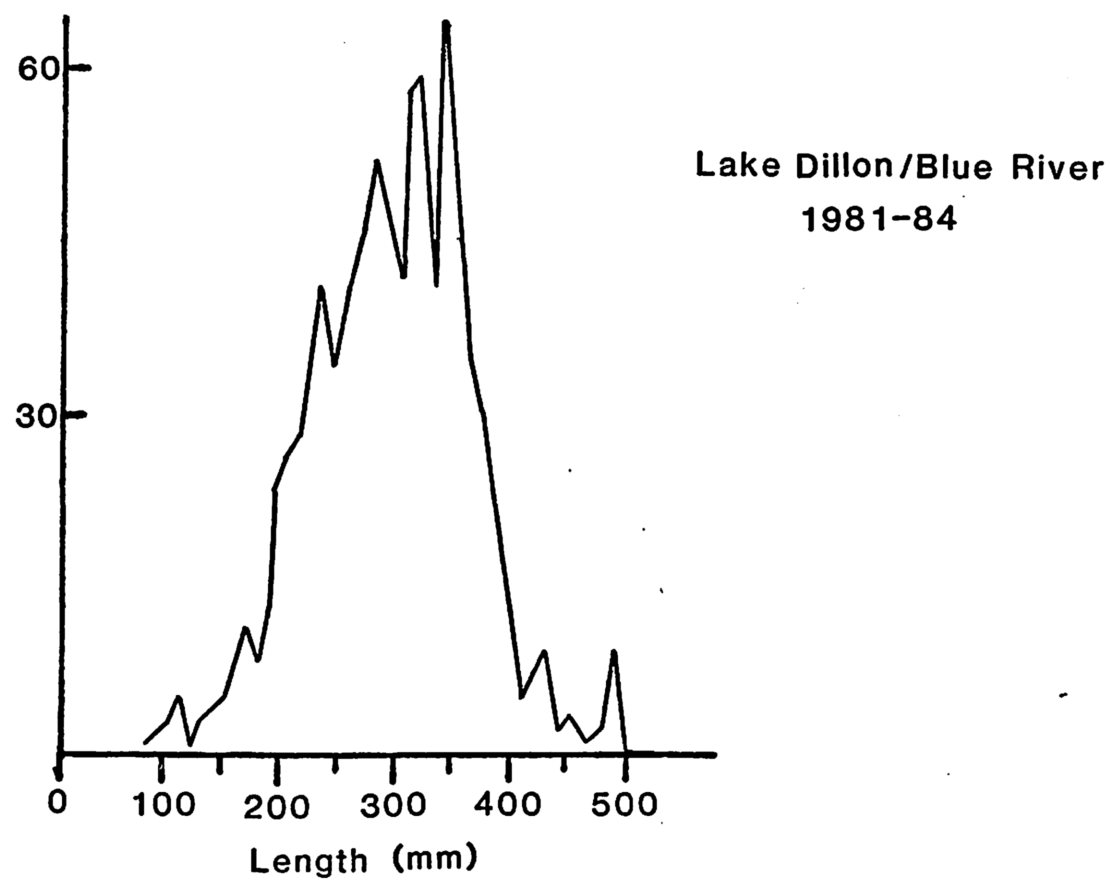


Figure 17. Comparison of brown trout length frequency distributions from Davis (1982) and the present study.

Kokanee salmon were stocked successfully for the last time in Dillon in 1976 (Bennett, pers. comm.). Natural reproduction has sustained the population since 1980. Mean length data in Table 9 shows kokanee have ranged in length from 201-247 mm since 1981. Data from 1977 (Stuber 1979) shows no dramatic difference in kokanee salmon size compared to the 1980's data. At that time, Stuber (1979) described adult salmon as stunted due to high survival with increased intraspecific competition for food, and a depleted forage base due to overgrazing. Mature kokanee salmon in 1977 averaged 240 mm in length while spawning stocks from the previous 2 years (1975-76) averaged 380 mm in length (Stuber 1979).

Table 9. Kokanee salmon catch rate by year and net type, and mean length by year.

Year	$\bar{X}$/net		$\bar{X}$ length (mm)
	Bottom	Floating	
1977	8.5	3.3	213
1981	2.3	--	201
1982	1.0	2.0	219
1983	1.5	4.9	247
1984	1.3	6.6	220

From population estimate data in Table 6, the kokanee salmon densities in Dillon in 1983 and 1984 were estimated at 23, 13, 3, and 12 fish/ac for the July, September, October and August estimates, respectively. Only 31% of these fish were 200 mm or larger. These estimates indicate that, at present, the kokanee are not particularly abundant in Dillon via natural reproduction, but growth has not noticeably improved. This suggests that food competition has not decreased and the forage base for the planktivorous salmon remains inadequate for maintaining a population with satisfactory fishery potential.

Stuber (1979) does not indicate that *Mysis* were observed in Dillon in 1977-78 from zooplankton, benthic macroinvertebrate or fish stomach sampling. Using samples collected previously by W. C. Nelson (Colo. Div. Wildl.), Stuber documents the change in the pelagic zooplankton community from 1975 to 1978 with the replacement of large *Daphnia* sp with smaller *Bosmina* sp as the dominant cladoceran. Stuber (1979) attributes this change to overgrazing from dense populations of kokanee salmon and small rainbow trout. Both species were stocked heavily in 1974-76. Davis (1982) indicates Dillon Reservoir supported a "very large" population of *Mysis*, presumably by 1979. Corroborating data from Nelson (1981) suggests a substantial expansion of a *Mysis* shrimp population occurred over 1978-80. In effect, *Mysis* have entered the Dillon ecosystem as a planktivorous competitor with kokanee salmon for the available zooplankton forage, and they have contributed to a changed composition of the zooplankton community to species less favorable to kokanee growth. At the same time *Mysis* do not appear to provide a satisfactory, alternative food source for the salmon.

Dillon Lake Sport Fishery

Fisherman effort showed a declining trend over a 4-year period from 1977 to 1980, with an apparent rebound in use in 1984 (Table 10). Harvest also declined notably from 135,700 fish in 1977 to 50-60,000 fish in 1978 through 1980. Unlike fisherman effort in 1984, harvest did not rebound but remained at 50,700. Total catch rate has continued to decline, with both shore and boat catch rates declining. Harvests of rainbow trout and kokanee salmon decreased. Harvests of brown and brook trout increased. Without the additional harvest of 13,300 coho salmon, the 1984 total harvest would have been almost 26% lower.

Table 10. Sport fishery statistics for Dillon Reservoir, 1977-1980 versus 1984. Parentheses indicate percentage of estimate attributed to shore fishing.

	1977	1978	1979	1980	1984
Hours	243,900(79)	143,200(79)	183,300	149,900	202,400(78)
Harvest	135,700(74)	60,100(81)	51,900	53,600	50,700(73)
Rb	19,500(87)	1,600(96)	27,200	25,700	15,800(82)
L	2,400(68)	4,100(86)	2,100	1,400	7,500(71)
B	600(61)	500(96)	200	600	1,500(88)
K	113,700(72)	53,800(80)	22,400	26,000	12,500(54)
C/h total	0.56	0.42	0.28	0.36	0.25
C/h shore	0.53	0.43	—	—	0.23
C/h boat	0.70	0.37	—	—	0.31

Harvest statistics for brown trout and kokanee salmon, both self-sustaining species at Dillon, demonstrate different patterns (Table 11). Harvest and catch rate for brown trout in 1984 were the best observed, both being approximately two-and-a-half times greater than the 6-year means for 1975-1980. Conversely, harvest and catch rate continued a declining trend for kokanee salmon with harvest at one-tenth and catch rate one-eighth the 1977 level.

Table 11. Harvest statistics for brown trout and kokanee salmon at Dillon Reservoir 1975-1980, 1984.

	Brown trout		Kokanee salmon	
Year	Harvest	C/F	Harvest	C/F
1975	4,300	.015	--	--
1976	2,400	.009	--	--
1977	3,700	.015	113,700	0.46
1978	4,100	.032	53,800	0.38
1979	2,100	.011	22,400	0.12
1980	1,400	.009	26,000	0.17
1984	7,500	.037	12,500	0.06

The length frequency distribution of angler-caught coho salmon demonstrates the probable impact that winter angling in 1983-84 had upon the stocked population (Fig. 18). Compared with the length frequency distribution of gillnet-sampled coho salmon (most of which were captured in the summer of 1984), the distribution of angler-caught cohos demonstrates the larger salmon were quite vulnerable during the winter season. The angler-caught coho data in Fig. 18 resulted from a one-day sample by 2-3 anglers on Feb. 12, 1984. Undocumented reports of fisherman activity and success during this winter (Bennett, pers. comm.) imply that angling success for the coho was significant. It is postulated from this that anglers may have removed most of the cohos as they approached 300 mm in length during the winter, spring and early summer, nullifying their potential as *Mysis* predators, and reducing chances of evaluating their growth potential in Dillon.

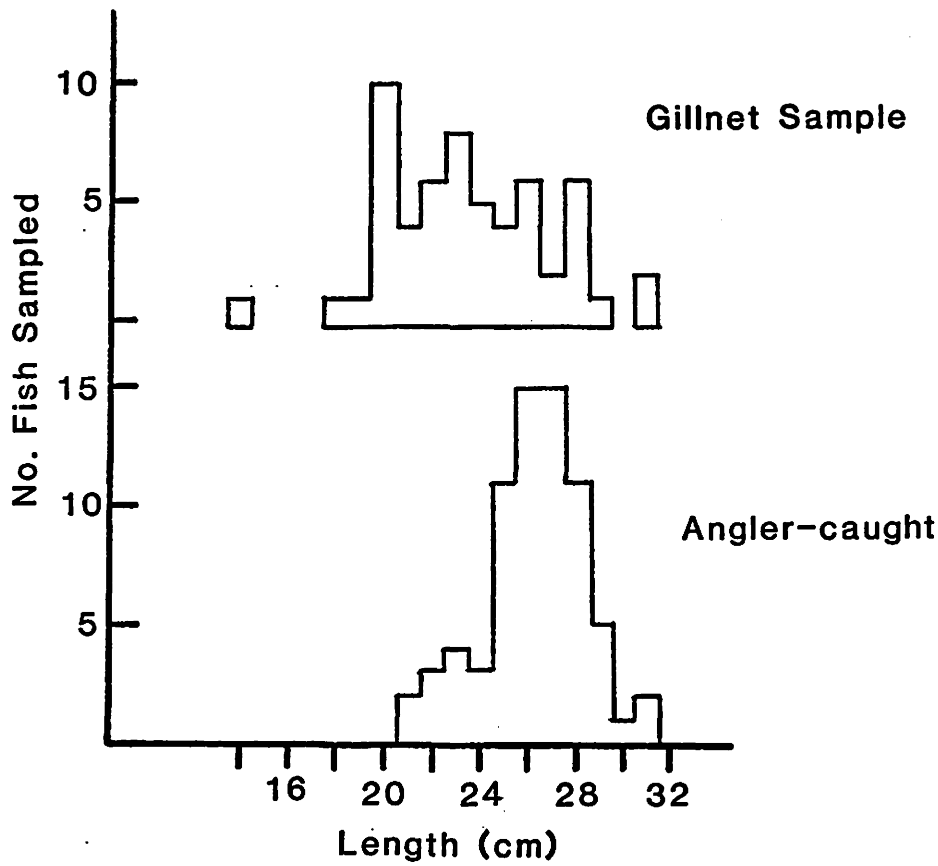


Figure 18. Comparison of coho salmon length frequency distributions for gillnet and angler-caught fish in Lake Dillon.

Job 2: To determine the effect of a developing *Mysis* population upon the food habits, age and growth of salmonid species in Turquoise Lake with particular emphasis on kokanee salmon and brown trout.

Job 3: To determine the food habits, age and growth characteristics of salmonid species, and particularly kokane salmon and brown trout in Green Mountain Reservoir, which provides a control with no *Mysis* present.

RESULTS

These two jobs are combined here because only very limited sampling was possible at Turquoise and Green Mountain. Despite the combination of 1983-84 data with that from previous records, sample sizes for kokanee and brown trout remain relatively small compared to Dillon Lake. Future study at these reservoirs should determine if brown trout can be sampled sufficiently to make valid comparisons with the Dillon population. Scale samples have been collected from the salmonids sampled in these two waters in 1983-84. Data analysis here are restricted to cursory observations that may suggest alternate or refined study hypotheses.

The preliminary data suggests that kokanee salmon grow significantly better in Green Mountain and Turquoise versus Dillon (Table 12). The mean lengths of Green Mountain and Turquoise Lake kokanee are 64% and 55% larger, respectively, than that of Dillon kokanee. No *Mysis* were observed in the stomachs of kokanee from Green Mountain or Turquoise, while the occurrence of large *Daphnia* sp. was common. The limited data from Turquoise Lake suggests that kokanee mean lengths here may be declining in recent years, but this possible trend may be a result of the increased stocking of fry from 100,000-300,000 periodically, up to 500,000 annually, as well as the potential impacts of an expanding *Mysis* population.

Table 12. Summary of mean lengths and size ranges for kokanee salmon and brown trout sampled by gillnets at Lake Dillon, Green Mountain Reservoir and Turquoise Lake.

		Kokanee salmon			Brown trout		
		Sample	Length		Sample	Length (mm)	
Lake	Years sampled	no.	Range	Mean	no.	Range	Mean
Dillon[a]	1977,79-84	294	120-330	220	1,080	90-670	332
Green Mtn[b]	1975-77,83	103	180-410	360	45	178-559	305
Turquoise[c]	1978,80,83	46	200-450	340	52	217-650	348

[a]Data from Stuber (1979) and present study
[b]Data from Sealing (1981) and present study
[c]Data from Nesler (1979, 1981b) and present study

The mean length for brown trout at Lake Dillon appears 8% larger than that for Green Mountain, and 5% less than that for Turquoise Lake. Here, too, Mysis have not been observed in the gut contents of the brown trout. These small size differences suggest no biologically significant difference in the growth potential for brown trout among the three lakes. Much more detailed study of the Green Mountain and Turquoise Lake brown trout populations would be necessary to verify this.

Stomach contents of salmonids sampled in 1983 in Turquoise were checked for incidence of Mysis ingestion. Only 2 lake trout out of 14 checked contained Mysis. These fish were 310 and 640 mm in length. One cutthroat, out of three captured, also had eaten Mysis. This fish was 190 mm long. These three fish were all included in the July 1983 sample. There was no evidence of Mysis ingestion among the salmonids in the October 1983 sample.

One of the conclusions in Nesler (1981b) was that lake trout had not been able to achieve a self-sustaining reproductive status in Turquoise Lake by 1980. The length frequency distribution of lake trout sampled at Turquoise in 1983-85, suggests this is no longer valid (Fig. 19). The last known stocking of lake trout occurred in 1977 (Nesler 1981b). The stocking record indicates stocked lake trout would have been 6, 8, 10, and 12 years old in 1983. Given the growth rate of lake trout in Turquoise estimated by Nesler (1981b), these fish all would have exceeded 400 mm in length in 1983. Seventy-two percent of the lake trout sampled since 1983 have been smaller, and presumably younger, verifying natural reproduction.

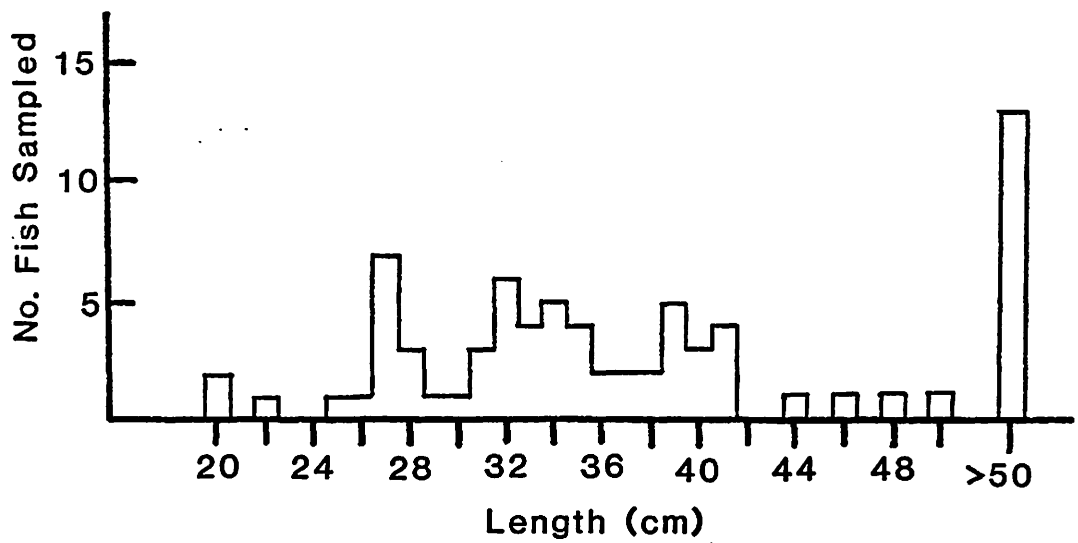


Figure 19. Length frequency distributions of lake trout sampled by gillnet in Turquoise Lake, 1983-85.

DISCUSSION - RECOMMENDATIONS

The presence of Mysis shrimp in Colorado's lakes and reservoirs resulted from a widespread impetus in fisheries management to improve the forage base for gamefish species, especially the salmonids. Based on some notable success in Colorado and elsewhere, introductions of Mysis accelerated with the potential promise of repeated success. Since then, intensive research has begun to document the side effects of these introductions as well as the primary impacts on the target gamefish species. The background on Mysis introductions and subsequent research is included in the attached Study Narrative, and summarizes the potential problems.

As indicated earlier, the results of surveys of the Mysis waters in Colorado have demonstrated the adaptability of Mysis to a range of aquatic ecosystems. Primarily, Mysis are established and quite abundant in Twin Lakes, Granby, Shadow Mountain, Grand Lake and Dillon. Small and/or expanding populations of Mysis occur in Turquoise, Ruedi and Taylor. Downstream importation of Mysis into Mary, Carter, Estes and Horsetooth has also occurred. Blue Mesa Reservoir and Green Mountain Reservoir are potential recipients of Mysis transplants via downstream transport. In other words, a significant percentage of Colorado's coldwater reservoir fisheries are (or may be) affected by the Mysis introductions of the early 1970's. Established shrimp populations in Jefferson, Mary, Estes, and Chalk lakes suggests Mysis may have been able to establish populations in the many smaller, high-elevation lakes (36) into which they were planted. An important point to be made is that introduced stocks of Mysis will probably affect drainages, not just individual bodies of water. The evidence of this already exists.

Eight lakes were checked for Mysis with negative, though inconclusive, results. Three were high lakes checked in 1976 soon after introduction. Any Mysis in these lakes may have simply been missed by the sampling effort. In two lakes, no Mysis were present in fish stomachs and another reservoir has been dried out several times. Only two waters, Lower Big Creek and Green Mountain, have shown evidence of Mysis declines to virtual "disappearance".

Nine reservoirs provided some information regarding the hypothesis of a warmwater surface strata providing large cladocerans (Daphnia spp.) a refuge from Mysis predation. It is implicit in this analysis that the mere presence of 14 C water in a reservoir does not guarantee the existence or perpetuation of a cladoceran zooplankton population. Obviously 14 C or warmer water would be required for a certain time period down to a certain depth to permit the cladoceran species to be self-sustaining. In general, lakes with abundant cladoceran populations and moderate to no Mysis populations had warmwater refuges that occupied 40% or more of the reservoir capacity at maximum development, and that had a duration of 90 days or more. Lakes with few or no cladocerans and abundant Mysis had thermal refuges less than 40% of reservoir capacity, and existing less than 80 days. Turquoise Lake and Ruedi Reservoir represent transition cases with abundant cladocerans, recently verified Mysis populations and intermediate refuge size or duration statistics. Experience at the other lakes would suggest the cladocerans will disappear at Turquoise Lake, while Ruedi may attain a coexistence status like Granby. Given the potentially large refuge at Taylor, it is plausible that coexistence of cladocerans and Mysis is likely, if the low-level shrimp population there continues to maintain itself. Using Taylor, Horsetooth, and Green Mountain as examples, it is possible that Mysis have difficulty in maintaining a population in reservoirs with large warmwater zones that restrict their coldwater habitat and limit their movements and food base. Bottom releases from these reservoirs may serve to further deplete the shrimp population via entrainment in the outlet flows. Another important point to consider is based on the age/size differential in migratory behavior of Mysis noted by Gregg (1976) at Twin Lakes. Juvenile Mysis were less constrained by light and temperature increases compared to the larger adults. This knowledge would have a significant bearing on data analyses and tests of the refuge hypothesis.

The impacts of Mysis on Daphnia are evident from a series of reports that dealt with a 320-surface-acre impoundment that receives water from both Twin Lakes and Turquoise Lake. In 1977-78 the Mt. Elbert Forebay was filled for the first time with Turquoise Lake water, and by 1978-79, Daphnia comprised up to 49 animals/liter and 50% of the zooplankton fauna (Boehmke et al. 1982). In 1980-81 this reservoir was drained for maintenance and repaired and refilled with Turquoise Lake water, however, Mysis were introduced into the forebay from Twin Lakes in 1981 (LaBounty and Sartoris 1982). By late 1981, Daphnia were uncommon and the Mysis population was estimated at 35 million in the forebay (LaBounty and Sartoris 1982). Daphnia and other cladocerans "disappeared" from the forebay in 1982 (LaBounty et al. 1984). In essence, a rapidly expanding Mysis population eliminated an abundant cladoceran population within one season in a cold monomictic reservoir with limited refuge capacity, and continual input of cladocerans from Turquoise Lake.

These data lend support to the refuge hypothesis and provide some rough parameters to measure by, but the sampling design described in the study narrative (Substudy Objective No. 1, Job 2) will need to be carried out to completion to document the biological and physical parameters definitely.

Mysis interact with salmonids as both a competitor for zooplankton forage and a forage organism itself. Results from this and other studies suggest that the various trout and char species will utilize Mysis as a food item to the degree in which their respective niches overlap in time and space. The impact of Mysis on lake trout growth has been documented in Griest (1976) and Nesler (1984) at Twin Lakes. The results at Jefferson Lake complement the Twin Lakes case. Both lake trout and Mysis inhabit the deep coldwater zones of reservoirs, and are in contact year-round. At Twin Lakes 88% of the lake trout sampled had ingested Mysis (Griest 1976). The addition of Mysis shrimp to the lake trout diet of Twin Lakes improved the growth rate an average of 17% for ages 1 through 5 (Nolting 1968; Griest 1976; Nesler 1984). However, in the extensive depth range available at lakes like Lake Tahoe, Mysis become pelagic in nature, frequenting a mid-water stratum, and making a significant portion of their population less susceptible to lake trout predation (Morgan et al 1978). At Granby, with approximately twice the vertical expanse of Twin Lakes, only 0-9% of the lake trout sampled had ingested Mysis (Wiltzius, unpublished data).

Kokanee salmon, on the other hand, compete directly with Mysis for zooplankton forage, due to their preference for cladoceran species (Nelson 1955; Finnell 1966, 1968; Foerster 1968; Cordone et al. 1971; Le Brasseur et al 1978; Stuber 1979; Lasenby and Langford 1973; Cooper and Goldman 1980; Lasenby and Furst 1981; Kinsten and Olsen 1981). At Lake Tahoe, California-Nevada and Pend Oreille Lake, Idaho, Mysis shrimp and kokanee salmon have become co-competitors for the available cladoceran zooplankton forage (Morgan et al. 1978; Goldman et al. 1979; Rieman and Falter 1981). Kokanee salmon failed to flourish and declined in both cases, while Mysis populations expanded. Morgan et al. (1978) noted a 23% decline in the mean spawner size of kokanee in Lake Tahoe since Mysis became abundant. In contrast, the single, most positive result of the Mysis introduction at Kootenay Lake, British Columbia, showed inclusion of Mysis in the kokanee diet contributed to an increase in the population's modal size from 21-25 cm to 26-35 cm, and to an increased maximum salmon size in excess of 45 cm (Northcote 1972). Mysids were utilized extensively as food by subadult and adult salmon in the west arm of the lake (60-80% frequency of occurrence), but not in the north or south arms (Northcote 1973). More recent hypotheses suggest this was the result of the hydrologic-morphometric character of the west arm, which serves as the outlet of the lake. Mysis are suspected to become entrained in the stronger currents of the west arm, and become vulnerable to predation. The kokanee occupied the midwater zone where this entrainment occurred, and were able to exploit Mysis as a food source. This phenomenon is not present in most standing waters, but other cases of opportunistic predation on Mysis are detailed later.

From the above data, the hypotheses were formed that: (1) Mysis would not be an important food item for kokanee salmon in Dillon Reservoir with less than 20% frequency of occurrence in stomach samples; and (2) the growth rate of Dillon kokanee would be 20% less than that of salmon in waters with no or low level Mysis populations and abundant cladocerans. Corollary hypotheses for Turquoise Lake and Green Mountain Reservoir stated kokanee salmon growth in these waters would be 20% better than demonstrated in Dillon for the same reasons. The results of the available data tend to reject the frequency of occurrence hypothesis and support the growth hypotheses. The results suggest that while Mysis were utilized by 22% of the kokanee salmon in Dillon, this substitution for an extirpated cladoceran forage base did not maintain favorable growth. The Kootenay Lake data indicate that the lack of growth in Dillon kokanee is more a function of quantity versus quality. Mysis are not available in quantity for a long enough period to enhance growth. Statisical testing of these hypotheses remains to be accomplished in future studies.

The trawl population estimates of kokanee suggest a significant decline in the salmon population over the 1983 season. The reasons for this decline are not certain. The midwater trawling technique appears promising, providing estimates of population size with small coefficients of variation, but it is possible the salmon moved out of the 0-60-ft sampling zone in a progressive manner over the season. Analyses of sonar graph recordings and age composition analyses of the samples may provide further information. Many of the larger catches of salmon by the trawl were made in the 40-60-ft stratum. Another explanation of the seasonal decline may be mortality due to an inadequate food supply in combination with exploitation by anglers. Given that anglers kept 88% of the salmon they caught in 1984, and assuming that only salmon above 160 mm were kept, this size of salmon represented 37% of the July population estimate, or about 28,000 fish. Kokanee and coho salmon harvest data from 1979-80 and 1984 indicate anglers may remove an average of 25,000 salmon in a summer season, or 89% of the estimated salmon population vulnerable to angling in 1983. This significant figure suggests that the trawl sampling may indeed be missing a segment of the adult salmon below the 0-60-ft stratum, but also suggests the scenario that the lack of suitable zooplankton forage for the "larger" salmon may be increasing their vulnerability to angling. Stuber (1979) noted the unusual statistic that 72-80% of the kokanee, normally a pelagic feeder, were being taken by shore fishermen, and suggested the salmon had resorted to an atypical foraging pattern in the face of inadequate zooplankton abundance. Shore fishermen accounted for 54% of the kokanee in 1984, suggesting the atypical pattern is still prevalent, though to a lesser degree. In comparison, Wiltzius (per. comm.) has noted the frequency of occurrence of Mysis in kokanee stomachs at Granby Reservoir was 19%, 25%, and 1% for 1981 through 1983 respectively. Kokanee growth at Granby has demonstrated drastic reductions in recent years and competition with Mysis is considered one of several important contributing factors. Martinez (unpublished data) has verified the competitive interaction of Mysis with kokanee for the cladoceran forage at Granby. Martinez noted that the only time kokanee and Mysis shared the same depth stratum in Granby was at night when Mysis migrated upward from deeper water and the salmon left the lake surface for the 10-20-m stratum. As sight dependent feeders, the kokanee were handicapped in exploiting the temporarily available Mysis shrimp. He also noted that only age 2+ and older salmon utilized Mysis to any extent. Wiltzius (pers. comm.) noted the frequency of occurrence of Mysis in the stomachs of age 1+ kokanee in Granby in 1984-85 was 11-14% for June and August samples.

Coho salmon were introduced into Dillon Reservoir on the premise that they would feed more selectively on Mysis shrimp, based on general knowledge that coho prefer larger food items and rely less on zooplankton than the kokanee. The limited results here do not support the hypothesis that coho would be more effective Mysis predators, since only 9% of the coho sampled had ingested Mysis compared to 22% for kokanee. As indicated earlier, angler impacts upon the larger coho salmon may have nullified the opportunity for analyses of both the Mysis predation and growth differential hypotheses. Angler impact upon experimental stocks of potential Mysis predators that are also gamefish will have to be addressed in future studies. Eighty percent of the coho salmon harvested were taken by shore fishermen during the 1984 summer season. This indicates they were actively foraging in the shallow littoral zones because: (1) acceptable food items were located there; (2) zooplankton and terrestrial insect forage in the pelagic zone was inadequate; or (3) the coho could not effectively locate or exploit the Mysis population in Dillon. Observations of coho and kokanee stomach contents and sonar tracking during the summer demonstrated they were often concentrated in the upper 10 m of the water column feeding upon pupae and hatched mature forms of Diptera on the surface, while Mysis were concentrated in a band below 10 m. At this point, the experiment with coho salmon could not definitely be termed a failure or a success.

Brown trout constituted the other gamefish common to Dillon, Green Mountain and Turquoise Lake. Study hypotheses stated that the growth rate of brown trout in Dillon was within 15% of that for browns in Green Mountain. Corollary hypotheses for Turquoise Lake and Green Mountain Reservoir stated that age-growth characteristics among the three reservoirs were similar. As stated previously, the verification of these hypotheses will require further, detailed study since the available data provided here resulted from a composite of very limited sample sizes for Green Mountain and Turquoise Lake brown trout. The mean length data does tend to lend support to the hypotheses with less than 10% differences noted. Gillnetting samples at Dillon demonstrated the predisposition of brown trout for the shallow littoral habitat of the reservoir. Mysis become readily available as forage for brown trout only at times when their seasonal pattern of migration brings the shrimp into the shallows. This occurs when cooling water temperatures become favorable in the fall. The data suggests this may be the pattern of association at Dillon. Also being sight feeders, brown trout appeared to rely heavily on isopods, pelecypods and amphipods in Dillon, based on their common occurrence in stomach samples. Brown trout appear to feed upon Mysis as the opportunity arises. At Twin Lakes, sampling in the outlet channel in April 1981 revealed brown trout feeding extensively on Mysis entrained in the outlet flows. Forty-seven brown trout were captured and as the live fish were processed and released, many were noted to regurgitate large numbers of Mysis. Eight of the nine mortalities checked were full of mysids. In Granby 5-14% of the browns checked contained Mysis (Wiltzius, pers. comm.).

This opportunistic approach to feeding on Mysis was also displayed by rainbow trout at Twin Lakes. Samples of rainbow trout in the Mt. Elbert forebay demonstrated 12 of 15 fish had literally gorged on Mysis, presumably entrained in powerplant pump-back flows (Nesler 1982). Wiltzius (pers. comm.) noted 6-57% of the rainbow trout checked from 1981-1983 at Granby contained Mysis. Bennett (pers. comm.) also noted rainbows utilizing Mysis extensively at the pump canal inlet to Shadow Mountain Reservoir.

Results of the brown trout sampling indicated that the proportion of larger fish is declining, both in the population and the spawning stock. The presence of a large Mysis population appears to have little relation to this decline since the relative abundance of small- to mid-range size browns appears increased in 1983-84. These fish should provide an adequate supply of recruits to larger size-classes. Increased harvest of brown trout in 1984 at the rate of 250% suggests an area of concern regarding angler impacts on the population, as well as upon the mortality of larger fish. More specific work needs to be done on brown trout growth, survival of spawners, effectiveness of fishing regulations in both the Blue River and Dillon, and impacts of reservoir drawdown upon year-class abundance.

MANAGEMENT GUIDELINES

The overall study objective was to develop guidelines for managing lakes with Mysis populations. As an introduced species, Mysis shrimp have not always fulfilled their potential as a fish food organism; therefore, management techniques that contribute to the control, suppression, or elimination of established Mysis populations may be desired. The alternatives discussed here will be generally grouped by lake types, gamefish species, introductions of Mysis predators, specific reservoir fisheries, and potential elimination of Mysis.

High Lakes

Due to the number, geographic location and remoteness of the high lakes which received plants of Mysis, our information here is the most superficial. It is still unclear how many of the salmonid species stocked or inhabiting the high lakes may interact with Mysis in these systems. Biologists should make note of the lakes in Table 1 that occur within their area. Future surveys at these lakes should specifically strive to determine if Mysis have become established and what fish species are utilizing mysids. In shallower lakes, Mysis would always be vulnerable to predation by most salmonids, but in deeper lakes, the migratory behavior of the shrimp may make them relatively inaccessible to all potential predators except the lake trout. An established, abundant Mysis population may be sufficient reason why certain species like rainbow and cutthroat, or why plants of fingerlings did not survive well in the deeper lakes. In shallow lakes like Chalk Lake, Mysis may be unable to flourish due to continual exposure to fish predation. In deeper lakes like Jefferson Lake, it is clear lake trout are a suitable gamefish to exploit the available mysid forage base, but in turn are relatively inaccessible as a deep water species to a large segment of the angling public that is likely to use these lakes. The impact of mysid introductions to high lake fisheries may be relatively imperceptible to the angling public.

Large Coldwater Reservoirs

The most serious impacts of Mysis occur in these waters since they generally represent major recreational fisheries and rely on rainbow trout or kokanee salmon to provide large harvests. Abundant populations of mysids have permanently altered the composition of the available zooplankton forage, so the use of fingerling rainbow in a put-and-grow fishery or the maintenance of a kokanee salmon fishery is more problematic than before. There existed some question on the capability of these oligotrophic waters to support populations of both of these salmonid planktivores, prior to the presence of mysids. Now, at best, the abundance of the preferred cladoceran forage base will be dictated by the development of a thermal refuge; and managers must judge how large a population of rainbow trout and/or kokanee salmon this reduced food base can support.

These large waters provide three distinct types of fisheries based on the three major zones or niches that exist--the shallow, warmer littoral zone, the open-water pelagic zone, and the deep water benthic zone. The latter two zones would interface at the thermocline, which tends to influence the distribution of the inhabitants of both zones. The key or objective will be to utilize gamefish species that are highly unaffected by Mysis or those that can effectively exploit the mysids. Recommendations by species include:

Lake trout--Clearly the most effective of Colorado's salmonids as a mysid predator, the lake trout is generally the sole fish inhabitant of the deep water reservoirs in conjunction with Mysis, and provides a boat fishery/ice fishery with quality-trophy size potential. Drawbacks are that more restrictive regulations are necessary to maintain a quality lake trout fishery and these fisheries support only a small percentage of the recreational potential of rainbow/kokanee fisheries. Reservoirs with large vertical expanse (i.e. 60+ m) appear to lessen the lake trout's effectiveness as a Mysis predator, since a large amount of the Mysis population remains pelagic and unavailable as lake trout prey. This appears to be the case at Granby and is supported by work done at Lake Tahoe (Morgan et al. 1978).

Brown trout--Appears as one of the gamefish species that is least affected negatively by mysids. Browns fulfill a role as a benthic predator of the littoral zones and may benefit from the opportunistic, seasonal use of mysids. This species would continue to provide a shore fishery whose quality and magnitude is more dependent upon water level fluctuations affecting its macroinvertebrate food base and fishing regulations affecting harvest and fish sizes. It should be noted though that browns were observed to feed extensively on Daphnia in Green Mountain and Blue Mesa reservoirs prior to the introduction of kokanee salmon (Nelson and Wiltzius, pers. comm.).

Rainbow trout--Limited experience at Twin Lakes indicates this species is an opportunistic Mysis predator. Summer-stocked, creel-size rainbow trout demonstrated some ability to convert to Mysis during the subsequent winter at Twin Lakes. This species is probably at a competitive disadvantage as a fingerling with Mysis for utilization of cladocerans, but unlike kokanee, rainbows may convert to a mysid diet at a smaller size due to its characteristic aggressiveness. More pelagic, lake-run strains of rainbow may be more effective than the current strain(s) used in mass production in Colorado. Stocking of rainbow during the fall season of high mysid availability in the littoral or pelagic zones might contribute to a successful winter-spring fishery.

Coho salmon--This species should receive more experimentation. Similar to the rainbow trout in feeding aggressiveness, coho salmon may utilize Mysis more extensively in the pelagic zone, and provide greater fishery benefits if protected from angling mortality.

Kokanee salmon--Without a cladoceran forage base, this species offers little as a gamefish or for a fishery in Mysis lakes. Unique conditions are necessary to permit this species to achieve any fishery potential in Mysis lakes.

Brook trout--There is still insufficient knowledge on how this species relates to Mysis. Its habitat and growth characteristics may be limiting factors in its value as a Mysis predator with significant fishery potential.

Specific Reservoir Fisheries

Lake Dillon--Emphasis in this lake has probably shifted to the brown trout due to the small size of kokanee. Possible alternatives include the introduction of lake trout and continued stocking of coho salmon. Both species would utilize the Mysis forage base, and the kokanee would serve as suitable forage for larger lake trout. Given the large quantity of available deep water habitat and abundant mysid population, fairly large plants of fingerling lake trout could be justified 1-2 years in succession with subsequent monitoring. Coho salmon deserve a more concerted effort at introduction and evaluation. It is apparent that ice-fishing should be temporarily suspended to permit either species to avoid some angling mortality, especially in their first winter, and achieve a larger size. Objectives would be for coho to provide the large magnitude boat fishery trout, brown trout in a shore fishery and lake trout as a quality fishery protected by a restricted harvest. Creel-size rainbow trout could be used sparingly in select bays and angler-use sites to take the pressure off of the other species and provide an interim fishery. Fall plants of catchable rainbows should also be experimented with here for a spring fishery. Dillon also appears as a suitable site for establishment of a forage fish species that utilizes mysids as food.

Turquoise Lake--Should be monitored to see what develops. An expanding mysid population should eliminate the cladoceran forage base, resulting in declines of the maximum size of kokanee salmon and the associated fishery. Lake trout numbers and growth may continue to increase with the mysid forage base. Given the continued success of the shore fishery for cutthroat or rainbow trout, this lake would probably evolve into a Twin Lakes type of fishery with put-and-take shore fishing and a boat fishery for lake trout. Similar to management techniques being evaluated at Twin Lakes, kokanee salmon may continue to be stocked in lesser numbers as a fish forage base for lake trout.

Twin Lakes--These lakes have been managed as a quality lake trout fishery and put-and-take rainbow trout fishery since 1961. Currently the lake trout rely on a mysid forage base, with experimental stocking of kokanee salmon to provide food and improved growth for larger lake trout. Kokanee are not expected to contribute to the fishery as a gamefish itself, and were selected as a potential forage species on the basis of availability and stocking precedent. It is not known at this point if the lake's forage base will adequately support enough age 0-2 salmon to contribute to lake trout growth significantly.

Lake Granby--The kokanee salmon fishery here is currently the subject of intensive research, so any recommendations for management options will be deferred to the completion of that work. This lake currently supports a quality-oriented lake trout fishery under evaluation, and has demonstrated the capability of supporting a relatively abundant biomass of kokanee salmon on the existing cladoceran forage base. The situation evident here would provide a suitable experimentation site to determine what quantity/quality of kokanee fishery can be managed for, given the continued coexistence of Mysis and cladoceran zooplankton populations. Previous data suggests kokanee exceeding 300 mm in length will feed extensively on Mysis. Granby probably offers an adequate forage base to get salmon up to this threshold size. Further research should be conducted to investigate the potential ramifications of this to the fishery.

Introductions of Potential *Mysis* Predators

The introduction of mysids into Colorado's waters occurred without full regard for the organism's impact to the aquatic ecosystem. Recommendations for further introductions of exotic species to remedy the negative impacts of *Mysis* are viewed here with considerable caution. Clearly more rigorous research evaluation would be warranted in any introduction projects proceeding past the discussion stage.

Introductions of gamefish species that might utilize mysids have already been discussed to some extent. The advantages of using a gamefish lie in direct enhancement of the fishery, greater public acceptance, numerous stocking precedents within the larger drainage, and less political-legal conflict. As general midwater species, the salmon (*Oncorhynchus*, excluding *O. nerka*) appear as the most compatible, and potentially direct predator on *Mysis* that could provide a fishery comparable to kokanee/rainbow trout. Other species with potential include Arctic char and splake.

Introductions of forage fish species present a more complex issue for the above reasons. From a biological perspective, the rainbow smelt (*Osmerus mordax*) and the deepwater sculpin (*Myoxocephalus quadricornis*) appear to be suitable forage fish species that utilize mysids extensively. The latter species is endemic with *Mysis relicta* and the lake trout, and serves as important forage for lake trout. The smelt and sculpin occupy midwater pelagic and deep water benthic zones, respectively, and used in combination (along with lake trout) might make significant utilization of the biomass tied up in an abundant *Mysis* population. In turn these two species may provide significant forage for larger lake trout, coho or king salmon. Introducing a forage species lengthens the food chain, resulting in a net loss of energy available for desired gamefish species, but in this context, the options may be a lesser magnitude, quality fishery versus one that is poor to nonexistent. This may apply particularly as a possible alternative to the current fishery at Lake Dillon.

Importation of *Mysis* to Other Waters

Mysis have demonstrated survivability to the stress of downstream transport and interbasin water diversions. The potential for the spread of *Mysis* by these mechanisms should prompt biologists to also determine what lakes in their regions may be affected by imports from *Mysis* lakes. Blue Mesa Reservoir and Green Mountain Reservoir are two major fisheries that may be particularly susceptible.

Elimination of *Mysis* Populations

The opportunities of eliminating *Mysis* from the lakes where their negative side effects are most severe (i.e., big coldwater reservoirs) appear the least likely to occur. Drawdown and chemical reclamation in the large reservoirs is generally not feasible. Evidence from Green Mountain, Taylor and Horsetooth Reservoir suggest mysids may have difficulty in maintaining themselves in environments where a significant warmwater zone limits their movements and food sources. Restricted to the deepest water of the reservoirs, the bottom outlet may further deplete their numbers via entrainment in outlet flows. This hypothesis should be tested given the option.

A relatively abundant population of lake trout have been unable to effectively deplete the *Mysis* in Twin Lakes. It is doubtful that any biological mechanism could eliminate a *Mysis* population, but a food web such as the lake trout-coho-smelt-sculpin-*Mysis* system described earlier for Dillon may sufficiently suppress mysid numbers to permit re-establishment of a cladoceran zooplankton community.

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APPENDIX A

Study Narrative, F-83, *Mysis*-Gamefish Studies

July 1, 1984 - June 30, 1986

STUDY NARRATIVE

State: Colorado

Project No. 5506X Name: Statewide Fish Research

Study No. F-83 Title: Mysis - Game Fish Studies

Period Covered: July 1, 1984 - June 30, 1986

Study Objective: Develop guidelines for managing lakes with Mysis populations.

Need:

Mysis shrimp were first introduced into Twin Lakes, Colorado, in 1957 as an experimental forage species for lake trout (Klein 1957). This introduction proved successful by 1969, with the presence of a relatively dense population of Mysis that was being utilized by the lake trout as food (Finnell 1972). During this same time period, the introduction and establishment of Mysis shrimp in Kootenay Lake, British Columbia, appeared to be responsible for dramatic increases in the size of kokanee salmon, and the subsequent improvement in the salmon fishery there (Northcote 1973). These successes provided the impetus for further introductions of Mysis into 51 lakes and reservoirs in Colorado from 1969 to 1975 (Finnell 1977) Twenty-two of these waters have since been surveyed and 14 are known to contain viable populations of Mysis. Included within these 14 waters are many of Colorado's largest coldwater lakes and reservoirs such as Grand Lake and Granby, Shadow Mountain, Green Mountain, Turquoise, Ruedi and Taylor reservoirs. The current status of Mysis introductions in the other waters stocked and the potential spread of Mysis into downstream waters is unknown.

Studies conducted since these introductions have provided a better understanding of the role Mysis plays in these lake ecosystems, and also have demonstrated some negative implications for Colorado's salmonid fisheries management. In most cases, *Mysis* were introduced into lakes containing kokanee salmon populations with the objective of simulating the success achieved at Kootenay Lake. It has been established in Colorado and elsewhere that both kokanee salmon and *Mysis* shrimp prefer large cladoceran zooplankton, especially *Daphnia* spp., for food (Nelson 1955; Finnell 1966, 1968; Foerster 1968, Cordone et al. 1971; LeBrasseur et al. 1978; Stuber 1979; Lasenby and Langford 1973; Cooper and Goldman 1980; Lasenby and Furst 1981; Kinsten and Olsen 1981). At Lake Tahoe, California-Nevada, and Pend Oreille Lake, Idaho, *Mysis* shrimp and kokanee salmon have become co-competitors for the available cladoceran zooplankton forage (Morgan et al. 1978; Goldman et al. 1979; Rieman and Falter 1981). In both cases the kokanee salmon have failed to flourish, and have even declined, while the *Mysis* population has expanded. Under the combined predation pressure of *Mysis* and kokanee salmon, cladoceran species have been eliminated or significantly reduced with major changes occurring in their normal seasonal patterns of abundance (Richards et al. 1975; Cloern 1976; Morgan et al. 1978; Furst et al. 1978; Goldman et al. 1979; Rieman and Falter 1981).

The virtual disappearance of *Daphnia* spp. in Twin Lakes, Colorado, following the establishment of *Mysis* has been noted by LaBounty and Sartoris (1981). Historically, kokanee salmon stocking in Twin Lakes has not produced a fishery since 1959. Recent unpublished data by Martinez (Colorado Cooperative Research Unit) and Nelson (Colorado Division of Wildlife) indicate similar changes are occurring in the cladoceran zooplankton of Granby, Grand Lake, Shadow Mountain and Dillon reservoirs. *Mysis* shrimp have proven to be omnivorous in their food habits, utilizing forage ranging from bottom detritus to algae to whatever zooplankton species is available. This flexibility provides *Mysis* with a competitive advantage over kokanee salmon or other planktivorous fish species when the preferred cladoceran species have been eliminated. Unpublished data from Wiltzius and Bennett (Colorado Division of Wildlife) indicate progressively poorer growth for kokanee salmon in Granby and Dillon since the establishment of Mysis in these reservoirs. Stuber (1979) demonstrated the inability of rainbow trout fingerlings to survive in Dillon, due in part to the lack of suitable zooplankton forage (cladocerans). Mysis are generally associated with deep, coldwater environments, but also exhibit a complex pattern of diurnal and seasonal migratory behavior (Gregg 1976). Since the shrimp's preferred habitat generally coincides with that of the benthic-dwelling lake trout, shrimp are available to the lake trout year-round in Twin Lakes. Morgan et al. (1978) has also noted, though, that in the large vertical expanse of Lake Tahoe, Mysis are essentially pelagic in nature, remaining in the lake's midwater zone, thus making a significant segment of their population unavailable as food for the lake trout. The migratory patterns exhibited by Mysis at Twin Lakes and elsewhere indicate the shrimp may be susceptible to fish predation for only limited periods of the day or year.

The essence of the problem is that another competitor has been introduced, along with our game fish species, for a limited zooplankton forage. Mysis has the potential for significantly reducing the preferred cladoceran food base of kokanee salmon and rainbow trout, without itself becoming a substitute food item to sustain populations of these two game fish species. Clearly, Mysis shrimp have become a permanent resident of Colorado's large coldwater reservoirs, and presents an emerging problem for fisheries management.

Expected Results and Benefits:

The 2-year period granted for this study is considered an initial phase in order to document the scope of the potential problem presented by Mysis shrimp introductions in Colorado waters. The establishment of *Mysis* populations in our coldwater lakes presents a fisheries management problem of unknown proportions. Results of preliminary research in Colorado and results from the scientific literature regarding potential effects of *Mysis* introductions suggest the establishment of *Mysis* populations in Colorado reservoirs may be significant because:

1. adverse competition with rainbow trout and kokanee salmon, two gamefish species comprising a major part of Colorado's sportfish harvest;
2. its establishment in many of Colorado's large coldwater reservoirs that are well known and popular recreational fisheries
3. the permanent status of *Mysis* in these large reservoirs, since no conventional means of eliminating the shrimp (i.e., complete drawdown, chemical reclamation) are feasible;
4. the potential downstream spread of *Mysis* to other waters, such as Blue Mesa Reservoir

The results of this study will address the current magnitude of these problems via the shrimp's impact upon the abundance and quality of important species of zooplankton forage, and the effects upon the age structure and growth of gamefish competing with *Mysis* for the available food supply.

The primary benefit of this study will be to provide guidelines for providing a reasonable and satisfactory fishery in lakes where the adverse effects of *Mysis* are evident. Some of these guidelines will be in the form of hypotheses regarding management alternatives, and will require evaluation. The results of this study will provide the direction for future research to test the effectiveness of these management alternatives. The presence of *Mysis* in Colorado's large coldwater reservoirs is considered to be only one aggravating element in the larger problem of the management of these waters as multi-species fisheries with a limited forage base. This study will serve as a preliminary investigation to address the larger problem of ecosystem management of coldwater reservoirs. Ecosystem management must not only address the sport fishery aspects but should also include the physical, chemical, forage base and socio-economical aspects as well.

SUBSTUDY OBJECTIVE NO. 1: To determine the status of zooplankton and *Mysis* populations in selected lakes and reservoirs that have had *Mysis* introductions.

Background:

An understanding of the effect of *Mysis* shrimp on zooplankton populations with regard to *Mysis* feeding behavior, food preferences and resultant changes in zooplankton species composition has been fairly well documented in previous studies (Lasenby and Langford 1973; Goldman et al. 1979; Cooper and Goldman 1980; Rieman and Falter 1981; Lasenby and Furst 1981; Kinsten and Olsen 1981). Preliminary data from Nelson (unpublished, Colorado Division of Wildlife) and Martinez (unpublished, Colorado Cooperative Research Unit) indicate that similar changes are occurring in Grand Lake, Granby Reservoir, Shadow Mountain Reservoir and Dillon Reservoir.

Martinez (unpublished data, Colorado Cooperative Unit) presents a hypothesis that *Mysis* and cladoceran zooplankton may coexist in situations where an adequate "thermal sanctuary" of 14 C or warmer water develops in a reservoir's surface layer, providing a zone for cladoceran zooplankters to exist free from *Mysis* predation. A similar hypothesis was also presented by Rieman and Falter (1981). Beeton (1960), Teraguchi (1969), Brownell (1970), Gregg (1976), Bowers and Grossnickle (1978), Morgan et al. (1978) and Rieman and Falter (1981) have found that light and temperature conditions are the most important factors controlling mysid migrations. Thermal gradients modify the intensity of mysid response to light conditions with juvenile shrimp being the least affected and least restricted by temperature (Gregg 1976). In all cases, *Mysis* were restricted from surface waters in late summer due to high (unfavorable) water temperatures. The presence and effectiveness of the 14 C thermal sanctuary will be examined for the study reservoirs from the data collected here.

In order to evaluate the effects of *Mysis* on zooplankton, data concerning zooplankton composition and abundance prior to the establishment of *Mysis* must be available. Including the waters named above, this zooplankton data base is available for Turquoise Lake, Ruedi Reservoir, Taylor Reservoir and Green Mountain Reservoir. All of these latter waters have had introductions of *Mysis* and they have been shown to contain small populations of *Mysis* shrimp that may potentially expand. From these eight waters, four were selected for intensive biweekly sampling. Granby and Dillon reservoirs will be included since they are major fisheries and contain established *Mysis* populations. Turquoise Lake was selected on the basis of containing an intermediate or low level *Mysis* population. Green Mountain Reservoir sampling indicated no *Mysis* present in 1983 and 1984, and thus zooplankton populations there may serve as a comparison or a control (i.e., cladoceran populations unaffected by *Mysis*).

Job Objectives:

Job 1: To determine the success or failure of past *Mysis* introductions, the relative abundance of the population, and its status (expanding, declining or static) given known introduction dates and past density data.

Approach:

Mysis have been introduced into a variety of habitats in Colorado from small, shallow high lakes up to very large and deep coldwater reservoirs. In order to understand the potential role of *Mysis* in Colorado and determine a management plan for lakes with *Mysis* populations, it is necessary to determine the extent of successful *Mysis* introductions, and how they have fared in these different habitats. Without compromising the intensive sampling efforts on the four primary study reservoirs, it would appear feasible and desirable to sample other waters for *Mysis* shrimp when the opportunity presents itself. The two primary means of sampling shrimp are benthic trawling and fish stomach content analyses. Trawl samples will provide quantitative estimates of shrimp density useful for comparative purposes. Three trawls will be made during the daylight hours in the deepest area of the lake. The samples will be made over a known distance on the lake bottom, or distance trawled will be calculated via sample time and boat speed. The number of shrimp sampled will then be related to an area of lake bottom sampled (i.e., number/m^2). Fish stomach analyses will indicate if the shrimp population is being utilized as food. Fish will be collected via the standardized fish population sampling procedures for Colorado lakes and reservoirs. Monofilament gillnets will be the primary gear used. The number of nets used will be determined by lake area. All salmonid fish species collected will be measured for length and weight. Scales will be collected for age and growth determinations. Stomach contents will be sampled via sacrifice of the specimen or with standard lavage techniques. Given a probable one-time sampling effort at these secondary study waters, both methods would be utilized. Replicated oblique sampling tows for zooplankton would also be conductd to provide qualitative data on species present. The list of waters stocked with *Mysis* shrimp, broken down by region, would be provided to regional biologists, so that they also could collect similar data, as the opportunity presents itself, on the lakes that have not been surveyed since *Mysis* stocking. Assistance by regional personnel presents the best method for surveying the greatest number of potential *Mysis* lakes.

The extent of the data analysis will depend on whether *Mysis* are collected or not. If no *Mysis* are collected, the zooplankton and fish data represent survey information that will be added to the data base for management purposes. The lack of *Mysis* in the samples do not prove that the shrimp are not present. If the presence of *Mysis* is established in a given water, the physical characteristics (i.e., surface area, depth, elevation) of the lake will be included with the biological data collected above in order to define the range of lake environments in which *Mysis* exist in Colorado. Zooplankton data will list species present in the samples in order of decreasing abundance. Average *Mysis* density and the range of densities observed will be provided for comparison with other *Mysis* lakes. Statistical significance between *Mysis* densities per lake is not an important biological consideration here. Length/weight and age-growth data collected from fish sampled in *Mysis* lakes will be compared with similar data for the sample species in similar lake habitats. This data may originate from DOW fish management surveys or in the scientific literature. A distinction will be made in the comparisons whether *Mysis* are included in the food of a given species or not. Stomach content analyses will be conducted to determine which fish species have ingested *Mysis*. Statistical tests to be used for fish data comparisons are described later. Since the primary purpose of the limited sampling effort described here is to determine the success or failure of *Mysis* introductions, no specific hypotheses will be formulated for this preliminary stage of investigation.

Job 2. To determine if changes have occurred in cladoceran species composition overall, and during each of the three seasonal thermal cycles: spring turnover, summer stratification, fall turnover, in the presence of *Mysis* populations.

Approach:

Each of the four primary study reservoirs will be sampled biweekly from May through November. Sampling will consist of depth profiles for temperature, dissolved oxygen, specific conductance and pH. Zooplankton will be sampled within three specific depth strata, using oblique tows with a Clarke-Bumpus sampler. The surface stratum, designated as 0 to 10 m in depth, will be sampled seven times; a mid-water stratum, designated as 10-20 m in depth, will be sampled five times; and a bottom stratum, designated as 20 m to the lake bottom, will be sampled three times. This sample scheme was designed by D. Bowden (CSU Statistician) and W. Nelson (Wildlife Research Leader) to achieve optimal whole lake zooplankton density estimates within the constraints of physical limitations of sample collection and processing. Location of specific sample sites on the four reservoirs for each depth stratum will be determined by random selection within a numbered grid covering the lake area included within the given depths. These stations will be used each month thereafter. Zooplankton samples will be processed according to standard dilution techniques with cladoceran zooplankton being counted by species. Distribution of *Mysis* shrimp over depth will be determined by samples collected with a Tucker trawl. *Mysis* will be sampled bi-weekly within the same depth strata sampled for zooplankton. On a given reservoir, *Mysis* will be collected during the evening and zooplankton during the following morning. Three *Mysis* samples will be collected per depth stratum at minimum. *Mysis* samples will also be analyzed by age class, separating juveniles from yearling and adult shrimp. Three benthic trawls for *Mysis* will also be conducted along with the mid-water Tucker trawl to determine the overall relative density of shrimp in the reservoir. The number of *Mysis* samples was chosen as a minimum for statistical analysis per depth category in conjunction with sample processing constraints.

Results of *Mysis*-zooplankton sampling will be given as mean densities per depth stratum, and related through regression analysis to show changes in zooplankton species composition and density over time and depth as compared to *Mysis* shrimp distribution over time and depth. Response curves will then be compared over time per depth stratum and over the different depth strata through the season for each lake.

Hypotheses to be tested here include:

1. Cladoceran abundance, either absolutely, seasonally or by depth strata, is inversely related to the density of *Mysis*. Cladoceran species composition and densities (by depth strata or weighted average) are available at variable dates and times for Granby, Dillon, Green Mountain, and Turquoise up through 1984. These two descriptive indices of the cladoceran zooplankton may be split into pre-*Mysis* and *Mysis*-present categories and compared for evidence of the reduction or elimination of certain species. Cladoceran abundance will also be examined relative to *Mysis* densities via depth distribution of the two organisms. Densities of each population will be compared for given depth strata. The proposed inverse relationship between the abundance of cladocerans and *Mysis* will be statistically tested by correlation-regression analysis of paired density estimates.

2. Cladoceran species of zooplankton will coexist with *Mysis* shrimp populations if the temperature of the surface layer of the lake equals or exceeds 14 C, thereby limiting the diurnal migration of *Mysis*, and providing a sanctuary for cladocerans (i.e., *Daphnia* spp.) from *Mysis* predation. Temperature profile data will be used

to identify the proposed thermal sanctuary of the lake. Cladoceran and Mysis densities within and outside the boundaries of this sanctuary will be correlated to test its significance.

SUBSTUDY OBJECTIVE NO. 2: To determine the effect of an established Mysis population upon the food habits, age and growth of salmonid populations in selected reservoirs.

Background:

Mysis shrimp may affect salmonid feeding habits by eliminating preferred cladoceran species of zooplankton and forcing the fish to substitute other organisms into their diet. This shift in food supply may have some effect upon salmonid survival and growth rate. These impacts will affect some fish species directly through food supply and other species indirectly through interspecific competition. Results from Northcote (1973), Morgan et al. (1978) and Martinez (unpublished) indicate the effect of Mysis on fish feeding habits may be seasonal and size dependent. Approximately a 23% decline has been noted in the mean spawner size of kokanee salmon in Lake Tahoe since Mysis became abundant (Morgan et al. 1978). Conversely, the growth rate of lake trout at Twin Lakes improved by an average of 17% for ages 1 through 5 after Mysis became abundant (Nolting 1968, Griest 1977, Nesler 1984). Other than lake trout, few other salmonid species in Colorado appear to utilize Mysis as food to any significant degree.

Pre-Mysis data on age and growth is available for some of the salmonids in four study reservoirs, and will permit a comparative analysis to determine any effects of an established Mysis population upon the age structure and growth rate of the populations of these species. The seasonal feeding pattern for the major salmonid species in the study reservoirs is fairly well documented only for kokanee salmon in Lake Granby. Preliminary results suggest that only older kokanee salmon exceeding 300 mm (12 in.) in length will feed extensively upon *Mysis*, but very few salmon within the population are achieving sufficient growth to reach this threshhold size (Wiltzius, pers. comm.). Preliminary data collected at Lake Dillon indicate some seasonal utilization of *Mysis* by both kokanee salmon and brown trout. Coho salmon were recently introduced into Dillon on the premise that this species would be more effective as a *Mysis* predator than kokanee salmon. This was based on knowledge of the coho's general preference for larger food items. Preliminary data on the coho salmon in Dillon suggest nothing significant regarding this species' food habits or growth relative to other salmonids in Dillon. Significant fishing mortality from winter to spring appeared to greatly reduce the abundance of the initial plants of larger fish. The coho salmon also seemed to be actively eating *Mysis* shrimp over the winter period. The larger fish may have continued to utilize *Mysis* through the summer if protected temporarily from fishing mortality.

Job Objectives:

Job 1: To determine if *Mysis* in Lake Dillon have changed the food habits, age structure or growth of kokanee salmon or brown trout, and evaluate the effectiveness of coho salmon as a *Mysis* predator and game fish.

Approach:

Gillnets and mid-water trawls will be used as the primary means of collecting fish samples. In June and October, a 20-ft trawl net will be used to estimate the population size of kokanee and coho salmon in the 0-60 ft surface zone of the reservoir. Samples will be taken at depth intervals of 0-20, 20-40, and 40-60 ft in the four major areas of Lake Dillon--the main lake, the Blue River arm, the Snake River arm, and Ten-Mile-Giberson Bay. The number of samples will be determined by the proportional volume of the three depth strata in each major area, and will change with differences in reservoir elevation between June and October. Trawl sampling will be the primary means of collecting salmon for age-growth and food habit analyses.

Standard coldwater monofilament gillnets will be used in August or September to collect samples of trout species in the reservoir. Brown trout will be the primary target species for age-growth analyses. Gillnet sampling will include all four major areas of the lake in order to be representative of the reservoir population of brown trout. Net sets will continue to be made until sufficient scale samples are collected from most of the size range of fish available.

All fish sampled will be enumerated by net location, measured for total length and weighed. Scale and stomach samples will be taken from five fish from each centimeter size group for age-growth and food habit analyses respectively. Age and growth analyses will be done by standard techniques. Stomachs will be processed to quantify the incidence of Mysis utilization, numbers of Mysis ingested, and their percent volume relative to the total stomach content volume. Other organisms ingested will be identified and categorized qualitatively as to their abundance. Quantitative food habit analyses will be conducted only on fish sampled by mid-water trawling. Stomach contents of fish sampled via gillnets will be checked for utilization of Mysis and noted by species. Hypotheses to be tested include:

1. Mysis are not important to the food base of kokanee salmon in Dillon Reservoir (less than 20% frequency of occurrence).

2. The growth rate of kokanee salmon in Dillon is 20% less than that of salmon in waters with no or low level Mysis populations and abundant cladocerans.

3. The growth rate of brown trout in Dillon is within 15% of that for brown trout in Green Mountain Reservoir.

4. Coho salmon are more effective *Mysis* predators (significantly greater percent frequency of occurrence), and achieve 20% better growth in Dillon than do kokanee salmon.

Comparisons of fish growth between species and between lakes will be conducted by regression analysis of respective growth curves. Comparisons of growth rates per fish species will be both age specific among reservoirs and by year class within reservoirs. This applies to Jobs 2 and 3 following. Food habit analyses will be based on percent occurrence of *Mysis*, and will be statistically tested for significance through a Chi-square contingency table based on three fish size groups (0-6 in., 6-12 in., 12 in. and greater), the presence/absence of *Mysis*, and the different lakes represented. The statistical tests described here will also apply to the tests of hypotheses in jobs 2 and 3.

Job 2: To determine the effect of a developing *Mysis* population upon the food habits, age and growth of salmonid species in Turquoise Lake with particular emphasis on kokanee salmon and brown trout.

Approach:

Turquoise Lake will be sampled monthly with gillnets in the same manner as outlined for Lake Dillon. Turquoise Lake represents an early stage condition of low level *Mysis* abundance in contrast to the large, established *Mysis* population in Lake Dillon. Results from Turquoise fish sampling will be similar in form and directly comparable to results from Lake Dillon with regard to salmonid species common to both waters. Hypotheses to be tested here include:

1. Kokanee salmon exhibit 20% better growth in Turquoise Lake versus kokanee salmon in Lake Dillon due to the presence of a cladoceran food supply.

2. Brown trout in Turquoise Lake have a similar growth rate to Lake Dillon brown trout due to their niche separation from *Mysis* shrimp.
3. Lake trout in Turquoise Lake will change their food base to include *Mysis* in direct proportion to the shrimp's density.
4. *Mysis* are not important as a forage organism for salmonids other than lake trout in Turquoise Lake (less than 20% frequency of occurrence).

Job 3: To determine the food habits, age and growth characteristics of salmonid species and particularly kokanee salmon and brown trout in Green Mountain Reservoir which provides a control with no *Mysis* present.

Approach:

Green Mountain Reservoir is located approximately 12 miles downstream from Lake Dillon on the Blue River. While the downstream spread of *Mysis* from Dillon to Green Mountain is always possible, and Green Mountain received an introductory *Mysis* plant in 1974, recent sampling in 1983 and 1984 has indicated no *Mysis* present. Green Mountain Reservoir thus serves as a form of control for comparison to the other reservoirs' fish populations. Green Mountain Reservoir would also be sampled monthly with gillnets in the same manner as Lake Dillon and Turquoise Lake. Hypotheses to be tested include:

1. Growth rates of kokanee salmon are 20% greater in Green Mountain Reservoir compared to Lake Dillon due to the presence of cladocerans and absence of *Mysis*.
2. Brown trout in Green Mountain Reservoir have similar age-growth characteristics in comparison to brown trout in the other study reservoirs.

Geographic Location:

1. Fort Collins Research Center - office and data analysis

2. Primary study reservoirs:

   Summit County - Lake Dillon, Green Mountain Reservoir

   Lake County - Turquoise Lake

   Grand County - Lake Granby

3. Secondary study reservoirs:

   Lake County - Timberline Lake, Crystal Ponds, Deckers Lake, Observatory Lake

   Grand County - Grand Lake, Shadow Mountain Reservoir

   Garfield County - Deep Lake, Stillwater Reservoir

   Gunnison County - Taylor Reservoir, Blue Mesa Reservoir

   Eagle County - Homestake Reservoir, Ruedi Reservoir

   Park County - Jefferson Lake

   Pitkin County - Lost Man Reservoir

   Douglas County - Cheesman Reservoir

   Boulder County - Gross Reservoir

   Larimer County - Chambers Lake

Personnel Assignments

		Man-days
Principal Investigator	T. Nesler	252
Part-time Technician	Vacant	120

Time Requirements (all jobs concurrent)

July to September 1984 - write study narrative, preliminary zooplankton/ *Mysis* sampling, selection of reservoirs for intensive study, sample design.

October to November 1984 - intensive limnological and fish population sampling at study reservoirs, evaluate spawning run of coho salmon at Lake Dillon

December 1984 to April 1985 - compilation of available data on study reservoirs, processing of zooplankton, scale and stomach samples, preliminary data analysis and tests of hypotheses, annual progress report.

May to November 1985 - continue biweekly limnological and monthly fish population sampling at study reservoirs, survey secondary *Mysis* waters with regional aid as opportunity presents itself.

December 1985 to June 1986 - process raw data, zooplankton, scale and stomach samples, data analysis, evaluation of *Mysis* impacts, tests of hypotheses, final reports and guidelines.

Yearly Costs

1984-85	$57,500
1985-86	60,800

Supervision and Cooperation

Wildlife Research Leader	T. Powell
Wildlife Researcher B	W. Wiltzius
Regional Fish Managers:	
Northwest Region	C. Sealing
Southeast Region	D. Wurm
Northeast Region	R. Nittmann

Related Federal Projects

A survey of Federal Aid Projects from 1981 through 1984 indicates there are no current or recent studies with a similar emphasis. Two Colorado Federal Aid Projects--Fish Forage Studies (F-53) and Kokanee Salmon Studies (F-79)--have applicability to this study. Fish Forage Studies deals with investigations of rainbow smelt as a forage fish, which includes the smelts' food habits and utilization of Mysis shrimp. Kokanee Salmon Studies are being conducted at Granby Reservoir, and deals with population dynamics, age and growth of kokanee salmon, and the utilization of Mysis shrimp by the major fish species.

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Date: March 19, 1985

APPENDIX B

Fish Species Abbreviation Detail for Table 1

R - rainbow trout
K - kokanee salmon
NP - northern pike
M - mackinaw
L - brown trout
SMB - smallmouth bass
LMB - largemouth bass
W - walleye
YP - yellow perch
WB - white bass
AMS - American rainbow smelt
N - cutthroat trout
B - brook trout
GO - golden trout
GR - grayling
Sp - splake
WF - whitefish