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THE RELATIVE ABUNDANCE OF OPOSSUM SHRIMP, MYSIS RELICTA, IN TWIN LAKES, COLORADO, USING A BENTHIC TRAWL

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FOREWORD

This report is one of a series presenting data on different aspects of the ecology of Twin Lakes, Colo., collected before operation commenced at the Mt. Elbert Pumped-Storage Powerplant. Data in this report, combined with other preoperation data will be used as a baseline for analyzing postoperation data in order to quantify the effects of pumped-storage powerplant operation. The overall objectives of this research are two-fold: (1) to maximize ecological resources at Twin Lakes while meeting the demands of water and power projects, and (2) to learn the effects of pumped-storage operation on lakes and reservoirs, especially oligotrophic lakes in montane situations. Studies similar to those at Twin Lakes, Colo., are being conducted at other locations with periodic workshops being held for the purpose of presenting and discussing the results obtained. The exchange of information results in a better understanding of pumped-storage effects, which in turn, leads to a more efficient planning process and greater protection of environmental features.

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PURPOSE

The data contained in this report are a significant part of the baseline pumped-storage operations information on the ecology of Twin Lakes, Colo., to which findings during the postoperative phase will be compared. Opossum shrimp make up a significant part of the zooplankton population and are an important element of the Twin Lakes food chain, particularly for the lake trout fishery. Significant alteration of the shrimp population should be reflected in populations of other plankton, and of the young lake trout. The information in this report will be useful to those interested in the limnology and fisheries of other cold-water lakes where opossum shrimp are found. In addition, those interested in methods of sampling opossum shrimp will find the information in this report useful.

INTRODUCTION

Twin Lakes are two montane lakes of glacial origin, located within the drainage of the Upper Arkansas River, 24 km south of Leadville in central Colo. (fig. 1). The lakes lie at an elevation of 2802 m. The maximum surface area of the upper lake is 263 ha and the maximum depth is 28 m. The maximum surface area of the lower lake is 736.5 ha and the maximum depth is 27 m. The lakes are dimictic, fluctuating water storage reservoirs with maximum surface temperatures of 14 to 18 °C. Depletion of hypolimnetic oxygen may occur during thermal stratification. A detailed description of the limnology of Twin Lakes is provided by Sartoris *et al.* (1977) [1].[1]

Mysis relicta were introduced into Twin Lakes in 1957 (Klein, 1957 [2]) in an attempt to establish an additional food source for the lake trout (*Salvelinus namaycush* Walbaum (fig. 2). By 1969, the population had expanded to the point where *Mysis* were collected in the lakes for introductions elsewhere (Finnell, 1977 [3]). Griest (1977) [4] determined that the shrimp were the primary food item for the lake trout in Twin Lakes by 1974.

The development of Twin Lakes for pumped-storage power generation prompted investigations to determine the potential impacts of power generation on the various aspects of the life history of *Mysis*. Gregg and Bergersen (1980) [5] determined that the major impact upon the shrimp would probably be mortality via turbulence following entrainment. Significant mortality to the *Mysis* population from power-plant operation would likely have adverse effects on the lake trout population and fishery.

Studies of the spatial and temporal distribution of the shrimp were initiated by the Colo. Div. of Wildlife in 1974 to determine their relative abundance. Two sizes of benthic sled-type trawls and two photographic techniques have been utilized to estimate *Mysis* densities. The majority of *Mysis* density data were generated using the two trawls, while photographic techniques developed by Finnell (1977 [6]) and Bergersen and Maiolie (1981) [7] were used to evaluate the sampling efficiencies of the trawls. Further studies were conducted to determine the relative sampling efficiencies between the two trawls. These studies provided a comparative evaluation of the relative abundance of *Mysis* using all available data collected during the preoperational study period.

This report presents *Mysis* density data collected during 1977–79, but utilizes data collected in 1974–75 for comparisons between the different-size trawls and between years sampled. Details of the 1974–75 shrimp data may be found in Finnell (1977) [6].

CONCLUSIONS AND RECOMMENDATIONS

1. The relative differences in *Mysis* abundance over time and depth may be adequately determined using a benthic sled-type trawl. The dynamics of *Mysis* distribution, as influenced by their extensive vertical and horizontal migrations, make estimations of the real or absolute density from benthic trawl data unlikely.

2. The comparison of *Mysis* density estimates from different lakes, and collected with various types and sizes of sampling gear, must account for size-selective differences in capture efficiencies, eliminate variability in *Mysis* distribution over time and depth, and consider differences in lake productivity. The difference in shrimp density estimates

[1]Numbers in brackets refer to entries in the Bibliography.

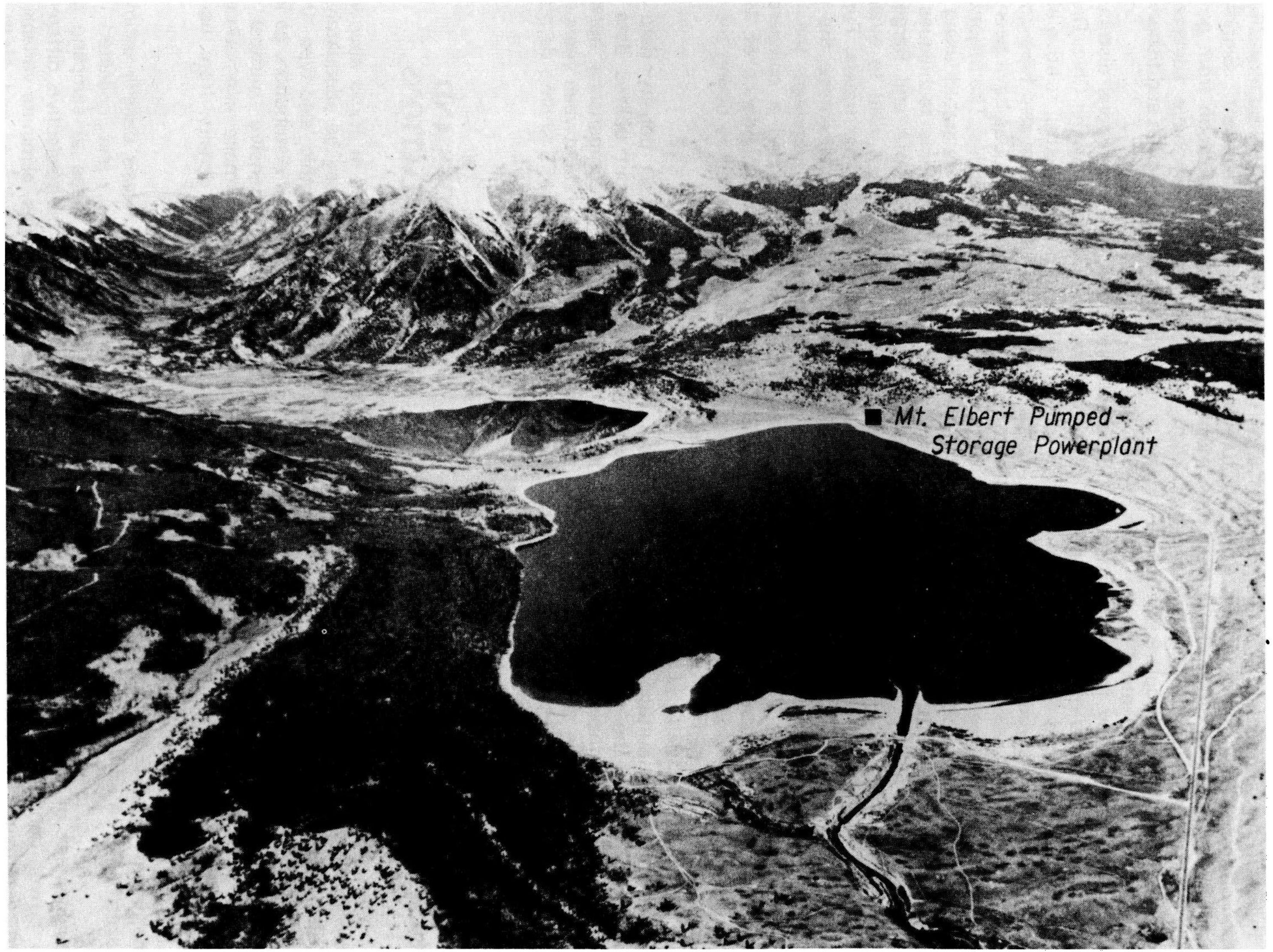

Figure 1.—Aerial view of the lower lake. Mt. Elbert is in the background, and the outlet works in the foreground. Photo P-915-D-79401

Figure 2.—Opossum shrimp (*Mysis relicta*). Photo P-915-D-79400

provided by the two trawls used was a result of the larger mesh size in the large trawl, which allowed a selective escapement of the small, juvenile shrimp.

3. Yearly differences in the relative abundance of *Mysis* in Twin Lakes are influenced by limnological factors affecting lake productivity and zooplankton abundance. This assumes a consistent sampling bias between years sampled.

4. Monthly differences in *Mysis* density estimates are influenced by the shrimp's migratory behavior relative to the sampling limitations of the trawl and also by specific limnological factors that predominate Twin Lakes in certain years.

5. Use of the *Mysis* density estimates generated by the benthic trawl for the evaluation of powerplant impacts is possible if increased mortality results in a reduced *Mysis* abundance below the range of preoperational estimates. Precautions concerning sampling consistency must be considered.

METHODS

A standardized scheme for sampling *Mysis*, using a benthic sled-type trawl, was developed in 1974 and used in 1975, 1977, and 1979 (fig. 3). Only limited sampling was accomplished in 1978. *Mysis* sampling at Twin Lakes was conducted from 1974 to 1975 by Finnell (1977) [6] and Gregg (1976) [8]. The sampling design for all studies combined systematic and stratified-random elements. Traverse lines were constructed through the middle of both lakes using permanent sampling stations 2, 3, and 4 as directional guiding points. In the lower lake, this line ran from the lake outlet, through stations 2 and 3, ending near the powerplant outlet. This line was divided equally into eight sampling sections, each approximately 0.4 km long. In the upper lake, the traverse line ran from inlet to outlet using station 4 as a midpoint, forming two sampling sections approximately 0.8 km in length.

Monthly sampling was conducted within each of these traverse line sections from June through November (table 1). Additionally, six stations in the lower lake and one in the upper lake were sampled monthly from depths greater or less than 15 m (fig. 3). Locations of these seven permanent stations were selected randomly for each of the six sampling months in 1974, 1975, 1977, and 1979. In the lower lake, three stations were located at depths greater than 15 m and three at depths less than 15 m. In the upper lake, the one station was located at a depth greater than 15 m. In 1978, only the traverse

Table 1.—Mysis *sampling stations for Twin Lakes*

Month	Lower lake			Upper lake	
	Traverse line stations	Random stations		Traverse line stations	Random stations
		>15 m	<15 m		
June	I thru VIII	$B_{1,2,3}$	$B_{1,2,3}$	IX, X	B_1
July	Same.	$C_{1,2,3}$	$C_{1,2,3}$	Same	C_1
August	Same	$D_{1,2,3}$	$D_{1,2,3}$	Same	D_1
September	Same	$E_{1,2,3}$	$E_{1,2,3}$	Same	E_1
October	Same	$F_{1,2,3}$	$F_{1,2,3}$	Same	F_1
November	Same	$G_{1,2,3}$	$G_{1,2,3}$	Same	G_1

line stations were sampled, and only in 2 months—August and September. On a yearly basis, 85, 17, and 103 samples were obtained in 1977, 1978, and 1979, respectively.

The sampling procedure consisted of lowering the trawl down through the water at the desired location while moving slowly forward in the boat to make sure the trawl settled on the lake bottom in an upright position. Line was stripped from the winch drum to maintain adequate slack and prevent unwanted movement once the trawl touched bottom. Approximately 90 m of line was used for deep stations (18 to 24 m) to ensure that the trawl remained on the lake bottom. At shallower stations (2 to 16 m), approximately 45 m of line was let out. The tubular aluminum frame of the trawl was weighted with 6.8 kg of lead from 1977 to 1979 to add stability and further promote bottom sampling. Sampling runs were conducted for 2 minutes, during which the mean speed of the towing vessel was determined by timing the passage of a float over the length of the vessel. Three float passages were timed for each run. Using the mean boat speed in meters per second over the 2-min sampling period, the distance traveled by the trawl was estimated. From 1977 to 1979, the mean boat speed was maintained within a range of 0.26 to 1.09 m/s and averaged 0.63 m/s (± 20 pct coefficient of variation) over 205 samples taken.

At the end of the 2-min period, the boat was stopped and reversed in direction to minimize further sampling by the trawl, which was rapidly winched to the lake surface. At the surface, the trawl net was washed to concentrate the shrimp into the metal bucket forming the cod end. The shrimp samples were then preserved in 10 to 15 percent formalin. Sampling was normally conducted between 0800 and 1100 hours. This time was selected because Gregg (1976) [8] found that 90 percent or greater of the shrimp were at the bottom of Twin Lakes by sunrise.

To facilitate counting samples of very large numbers of *Mysis*, an electric subsampler described by Gregg (1976) [8] was used. Preliminary chi-square analysis of *Mysis* density estimates based on subsample numbers were performed by Gregg (1976) [8] and no significant differences ($P \leq 0.05$) were found. Equality of subsamples was assumed for the years 1977–79. The density of *Mysis* at each station was determined by dividing the total number of shrimp per sample by the area of lake bottom sampled by the trawl. The area sampled was determined to be the product of the distance traveled by the trawl and the width of the trawl mouth.

Two different size trawls were used during the study period (figs. 4, 5, 6, and 7). In 1974–75, a large trawl with a 60- by 150-cm mouth and 3- to 6.4-mm-mesh net was used. In 1977–79, a smaller trawl with a 27- by 45-cm mouth and 0.7- to 1.0-mm-mesh net was used. During sampling with the large trawl in 1979, *Mysis* were observed escaping through the mesh as the trawl was held at the surface, and it was postulated that the larger trawl was not sampling small shrimp effectively, thus resulting in lower density estimates relative to the smaller trawl. Twenty-eight replicate samples using the two trawls at given stations were made in July, August, September, and October 1979, with the objectives of determining relative sampling efficiencies and a conversion factor to make the data sets for 1974–75 (Finnell, 1977 [6]) and

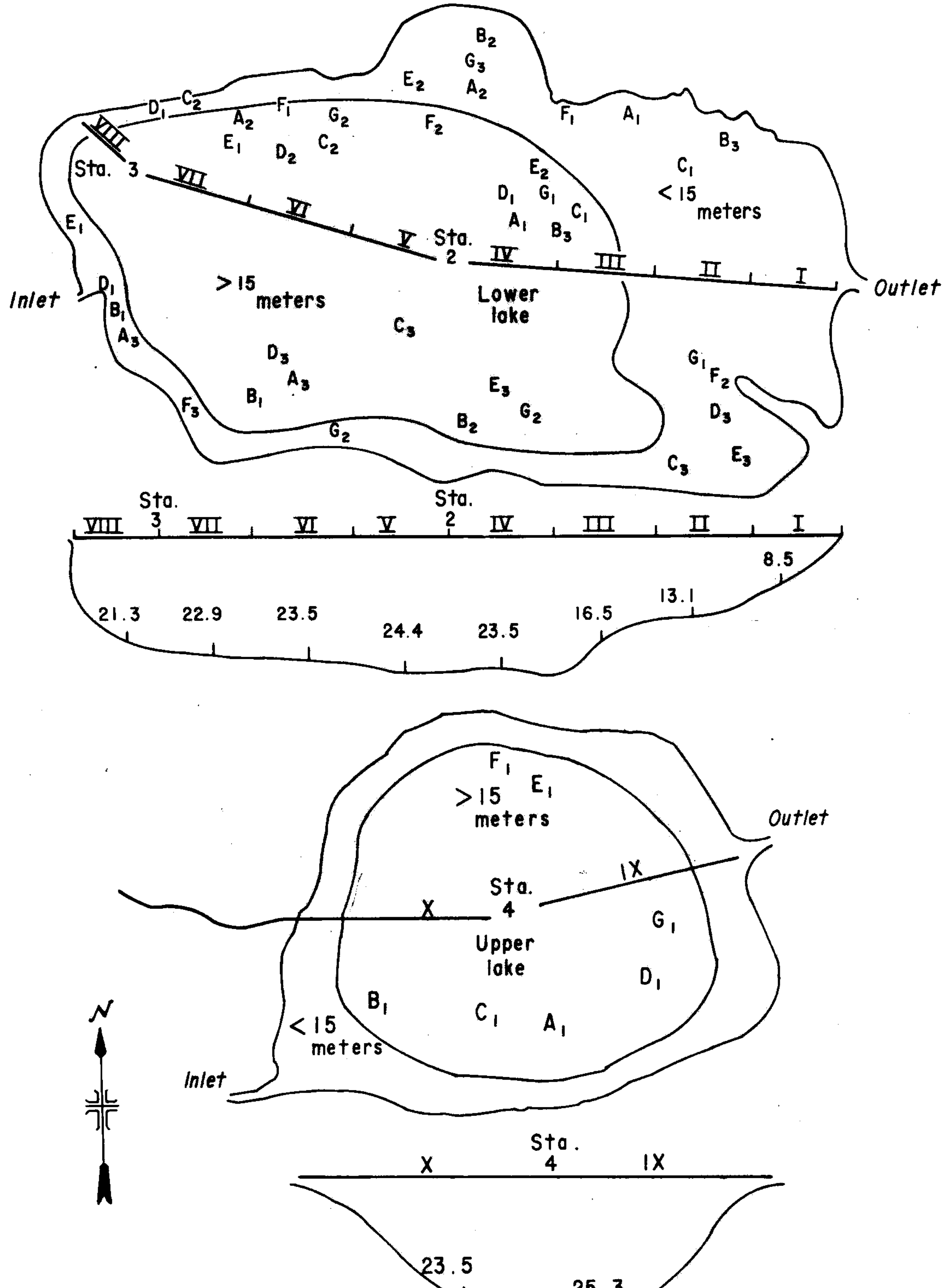

Figure 3.—*Mysis* sampling stations for Twin Lakes.

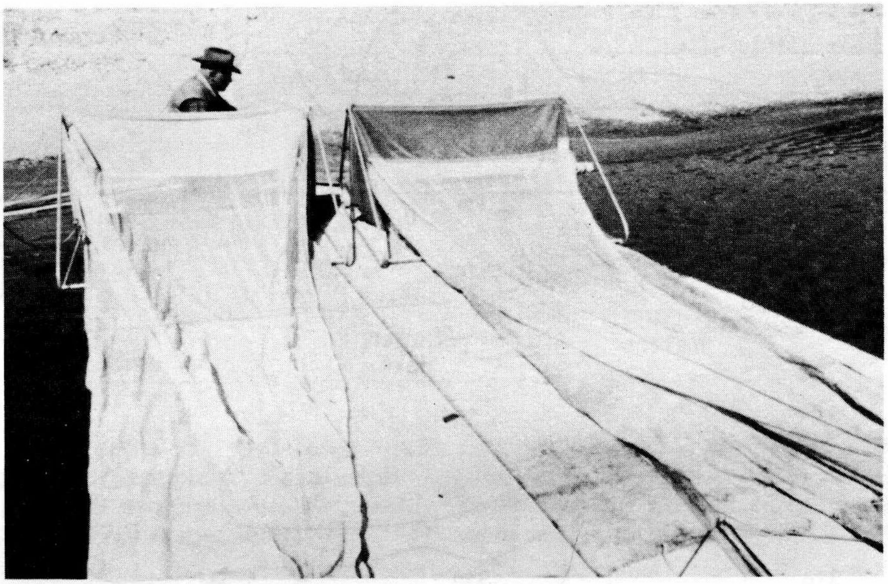

Figure 4.—Large benthic sled-type trawl used in 1974–75. Photo P-801-D-79722

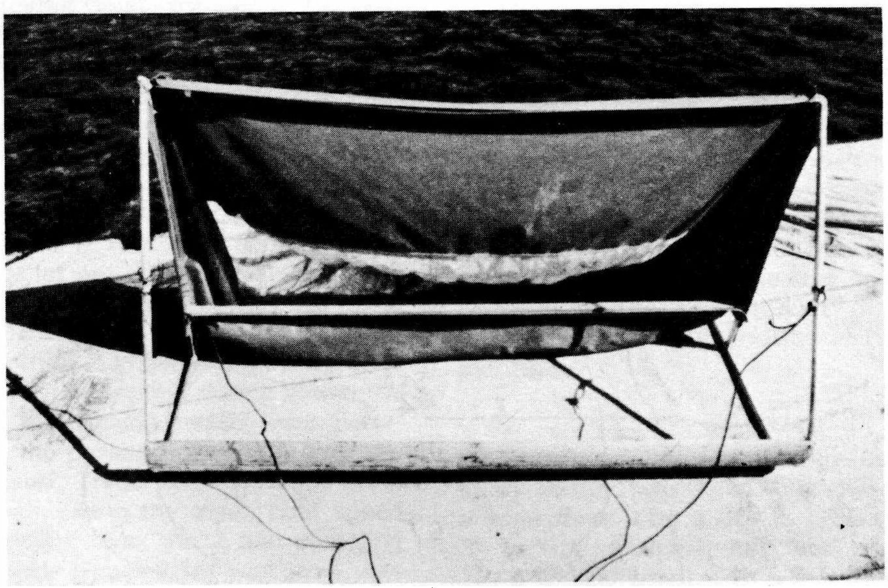

Figure 5.—Front view of large trawl. Photo P-801-D-79723

1977–79 comparable. To increase the representativeness of the comparison, stations where replicate sampling was conducted were divided monthly among lower lake-deep stations, lower lake-shallow stations, and upper lake stations on a 4:3:1 ratio. A lost sample and limiting weather conditions altered this ratio in August (3:3:1) and October (4:1:0), respectively. Each sample was conducted according to the procedure described earlier. Once the boat was positioned at the desired location, a marker buoy was used to identify the starting point. At the completion of one sample, the boat would be returned to the same position, and another sample would be taken in the same direction with the other trawl. Given the method of placing the trawl on the lake bottom, it was assumed that the two trawls never followed the same path exactly. The two trawls were also alternated on which was used first in a replicated sample.

Figure 6.—Small benthic sled-type trawl used in 1977–79. Photo P-801-D-79724

These *Mysis* samples were processed in the same manner as described earlier for density estimation and were further processed for length frequency measurements. Following density estimation on a given sample, the entire sample would be subsampled again to obtain approximately 400 shrimp. All shrimp within this subsample would be measured for length to the nearest millimeter (i.e., 14.5 to 15.4 = 15 mm) from the tip of the rostrum to the tip of the telson, disregarding setae. Sample sizes for the length frequency analyses for the large and small trawls were 10 389 and 10 934 shrimp, respectively.

RESULTS

Small Trawl Samples—1977–79

Mysis shrimp densities varied considerably over the 205 samples collected from 1977 to 1979, ranging from 0 to 355 shrimp/m^2 (tables 2 and 3). Categorizing the sample stations as deep (> 15 m) or shallow (< 15 m), monthly *Mysis* density estimates appeared greater in the deep stations of the lower lake for both 1977 and 1979 (table 4). Using the *t*-distribution for comparisons ($P < 0.05$), these differences between deep and

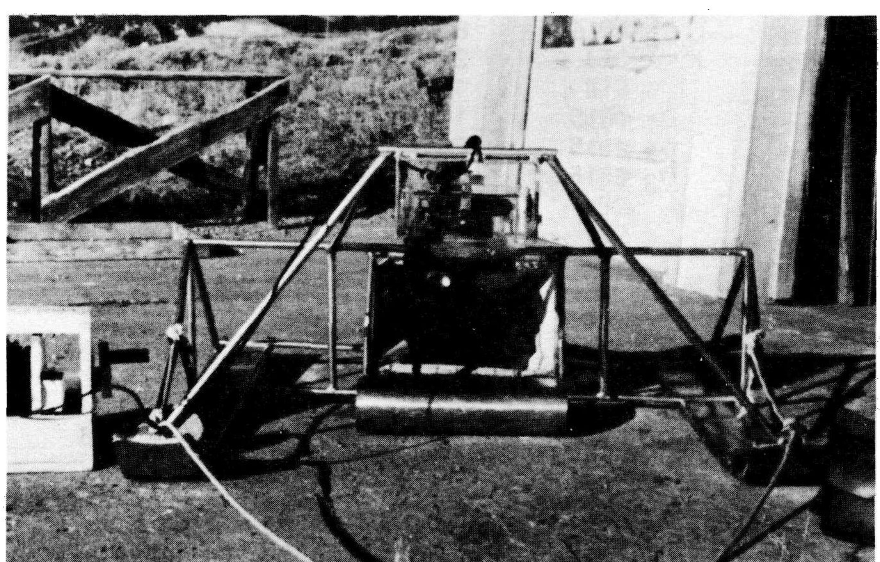

Figure 7.—Front view of small trawl. Photo P-801-D-79725

Table 2.—Mysis *density estimates for the lower lake, 1977–79.*

Month and year	Shallow or deep	Station	Estimated density No./m²	Trawl speed m/s	Estimated lift-off %	Corrected density No./m²
June 1977	Shallow	I	10	0.47	—	—
		II	5	.66	—	—
		$B_1 < 15$	40	.63	—	—
		$B_2 < 15$	19	.60	—	—
		$B_3 < 15$	3	.58	—	—
	Deep	III	8	.70	—	—
		IV	14	.63	—	—
		V	35	.66	—	—
		VI	22	.63	—	—
		VII	29	.63	—	—
		VIII	72	.66	—	—
		$B_1 > 15$	64	.66	—	—
		$B_2 > 15$	22	.63	—	—
		$B_3 > 15$	125	.63	—	—
July 1977	Shallow	I	0	.65	—	—
		II	0	.59	—	—
		$C_1 < 15$	4	.54	—	—
		$C_2 < 15$	168	.51	—	—
		$C_3 < 15$	2	.76	—	—
	Deep	III	159	.46	0	—
		IV	157	.42	0	—
		V	68	.40	0	—
		VI	35	.44	0	—
		VII	51	.26	0	—
		VIII	62	.31	0	—
		$C_1 > 15$	156	.51	9	171
		$C_2 > 15$	163	.49	3	168
		$C_3 > 15$	83	.48	1	84
August 1977	Shallow	I	22	.46	—	—
		II	18	.51	—	—
		$D_1 < 15$	11	.57	—	—
		$D_2 < 15$	25	.65	—	—
		$D_3 < 15$	14	.54	—	—
	Deep	III	160	.51	9	176
		IV	49	.40	0	—
		V	205	.57	24	270
		VI	156	.51	9	171
		VII	171	.57	24	225
		VIII	101	.61	34	153
		$D_1 > 15$	25	.76	72	89
		$D_2 > 15$	107	.65	44	191
		$D_3 > 15$	90	.54	16	107
September 1977	Shallow	I	0	0.42	—	—
		II	30	.54	—	—
		$E_1 < 15$	1	.48	—	—
		$E_2 < 15$	0	.34	—	—
		$E_3 < 15$	20	.54	—	—
	Deep	III	90	.51	9	99
		IV	1	.55	19	1

Table 2.—Mysis *density estimates for the lower lake, 1977–79.*—Continued

Month and year	Shallow or deep	Station	Estimated density No./m²	Trawl speed m/s	Estimated lift-off %	Corrected density No./m²
		V	0	.48	1	0
		VI	0	.57	24	0
		VII	98	.54	16	117
		VIII	168	.76	72	600
		$E_1 > 15$	47	.76	72	168
		$E_2 > 15$	49	.46	0	—
		$E_3 > 15$	150	.54	16	179
October 1977	Shallow	I	51	.51	—	—
		II	45	.42	—	—
		$F_1 < 15$	34	.57	—	—
		$F_2 < 15$	58	.42	—	—
		$F_3 < 15$	6	.52	—	—
	Deep	III	137	.54	16	163
		IV	154	.48	1	156
		V	126	.51	9	138
		VI	67	.40	0	—
		VII	54	.57	24	71
		VIII	45	.46	0	—
		$F_1 > 15$	113	.48	1	114
		$F_2 > 15$	286	.48	1	289
		$F_3 > 15$	88	.59	29	124
August 1978	Shallow	I	16	1.02	—	—
		II	39	0.76	—	—
		II	18	.95	—	—
	Deep	III	40	.87	—	—
		IV	148	.78	—	—
		V	152	.78	—	—
		VI	104	.54	—	—
		VII	41	.71	—	—
		VIII	83	.73	—	—
September 1978	Shallow	I	101	0.61	—	—
		II	105	.69	—	—
	Deep	III	127	.95	—	—
		IV	141	.82	—	—
		V	144	.82	—	—
		VI	127	.78	—	—
		VII	151	.78	—	—
		VIII	140	.76	—	—
June 1979	Shallow	I	6	.68	—	—
		II	44	.85	—	—
		$B_1 < 15$	35	.87	—	—
		$B_2 < 15$	15	.87	—	—
		$B_3 < 15$	0.3	.76	—	—
	Deep	III	10	1.09	—	—
		IV	91	0.90	—	—
		V	59	.59	—	—
		VI	157	.61	—	—
		VII	78	.65	—	—
		VIII	88	.80	—	—

Table 2.—Mysis *density estimates for the lower lake, 1977–79.*—Continued

Month and year	Shallow or deep	Station	Estimated density No./m²	Trawl speed m/s	Estimated lift-off %	Corrected density No./m²
		$B_1 > 15$	16	.82	—	—
		$B_2 > 15$	27	.71	—	—
		$B_3 > 15$	34	.76	—	—
		III	23	.71	—	—
July 1979	Shallow	I	8	.55	—	—
		II	94	.62	—	—
		$C_1 < 15$	91	.67	—	—
		$C_2 < 15$	16	.99	—	—
		$C_3 < 15$	177	.76	—	—
	Deep	III	90	.64	42	155
		IV	114	.62	37	181
		V	239	.58	26	323
		VI	195	.67	49	382
		VII	209	.70	57	486
		VIII	33	.67	49	65
		$C_1 > 15$	170	.72	62	447
		$C_2 > 15$	14	.68	52	29
		$C_3 > 15$	66	.70	57	153
August 1979	Shallow	I	0.2	0.68	—	—
		II	4	.67	—	—
		$D_1 < 15$	9	.52	—	—
		$D_2 < 15$	2	.61	—	—
		$D_3 < 15$	19	.72	—	—
	Deep	III	—	—	—	—
		IV	136	.76	72	486
		V	48	.67	49	94
		VI	157	.68	52	327
		VII	58	.65	44	104
		VIII	311	.63	39	510
		$D_1 > 15$	143	.66	47	270
		$D_2 > 15$	214	.64	42	369
		$D_3 > 15$	137	.62	37	217
September 1979	Shallow	I	12	.64	—	—
		II	81	.65	—	—
		$E_1 < 15$	21	.64	—	—
		$E_2 < 15$	46	.61	—	—
		$E_3 < 15$	83	.62	—	—
	Deep	III	179	.64	42	309
		IV	44	.61	34	67
		V	355	.62	37	563
		VI	278	.64	42	479
		VII	235	.67	49	461
		VIII	63	.62	37	100
		$E_1 > 15$	178	.64	42	307
		$E_2 > 15$	101	.64	42	174
		$E_3 > 15$	135	.65	44	241
October 1979	Shallow	I	2	.68	—	—
		II	32	.63	—	—
		$F_1 < 15$	12	.67	—	—

Table 2.—Mysis *density estimates for the lower lake, 1977–79.*—Continued

Month and year	Shallow or deep	Station	Estimated density No./m²	Trawl speed m/s	Estimated lift-off %	Corrected density No./m²
		$F_2 < 15$	0.4	.64	—	—
		$F_3 < 15$	0.1	.71	—	—
	Deep	III	188	.62	37	298
		IV	36	.63	39	59
		V	134	.67	49	263
		VI	192	.63	39	315
		VII	198	.64	42	341
		VIII	95	.61	34	144
		$F_1 > 15$	160	.58	26	216
		$F_2 > 15$	54	.64	42	93
		$F_3 > 15$	184	.61	34	279
November 1979	Shallow	I	27	0.78	—	—
		II	29	.72	—	—
		$G_1 < 15$	10	.83	—	—
		$G_2 < 15$	30	.63	—	—
		$G_3 < 15$	37	.64	—	—
	Deep	III	116	.54	16	138
		IV	92	.61	34	139
		V	327	.57	24	430
		VI	63	.58	26	85
		VII	122	.57	24	161
		VIII	48	.65	44	86
		$G_1 > 15$	62	.61	34	94
		$G_2 > 15$	84	.55	19	104
		$G_3 > 15$	44	.57	24	58

shallow stations were found to be significant in July, August, and October of 1977, and August, September, and October of 1979. *Mysis* density estimates in the lower lake-deep stations also appeared greater than those in the upper lake in each month for both years with the exception of June and September 1977. These differences between upper and lower lake-deep stations were significant for July 1977, and August, September, and October of 1979.

On a seasonal mean basis (June–November mean), *Mysis* densities in the deep basin of the lower lake were four times greater than those estimated for the shallow area of the lower lake in both 1977 and 1979. This difference was significant for both years. The seasonal estimate of *Mysis* density for the lower lake-deep stations was 1.5 times greater than the upper lake estimate in 1977 and five times greater than the upper lake estimate in 1979. Only the difference in 1979 was statistically significant. Comparing the lower lake seasonal estimates only, the 1979 deep-station estimate was significantly greater than that for 1977, while the shallow-station estimates for 1977 and 1979 were similar. In the upper lake, the 1977 estimate was significantly greater than that for 1979. The 95-percent confidence intervals for these estimates indicate that the greatest variation in *Mysis* densities was associated with the upper lake stations and shallow stations of the lower lake.

Large/Small Trawl Comparisons

Replicate samples, using the large and small trawls, involved 15 samples from the deep basin of the lower lake, 10 samples from the shallow areas of the lower lake and three samples from the upper lake (table 5). The mean *Mysis* density of the large trawl samples was 66 shrimp/m²

(95 pct confidence interval ± 47 pct) versus 97 shrimp/m² (95 pct confidence interval ± 39 pct) for the small trawl, but these means were not significantly different ($P > 0.05$). The lack of a significant difference was attributed to the sample design, which incorporated the variability in *Mysis* distribution between the upper and lower lakes, deep and shallow stations, and within upper lake and shallow-station samples. Given the limited number of trawl samples possible per category (month, lake, and depth), pooling of all samples into a general mean was necessary. The smaller sample sizes for each category caused a slight decrease in the width of the above confidence intervals for the lower lake-deep station estimates for both trawl sizes. Considerable increases (± 70 to 293 pct), however, were found in the width of the confidence intervals for both trawl sizes for the lower lake-shallow and upper lake estimates. Sampling bias within the small trawl sample also contributed to the lack of statistical significance.

Length frequency distributions of the samples from the two trawls were both bimodal, and

Table 3.—Mysis *density estimates for the upper lake, 1977–79.*

Month and year	Station	Estimated density No./m²	Trawl speed m/s	Estimated lift-off %	Corrected density No./m²
1977					
June	IX	114	0.66	—	—
	X	112	.66	—	—
	B_1	59	.63	—	—
July	IX	26	.51	9	29
	X	21	.57	24	28
	C_1	39	.70	57	91
August	IX	46	.57	24	61
	X	80	.51	9	88
	D_1	50	.51	9	55
September	IX	71	.61	34	108
	X	140	.59	29	197
	E_1	13	.54	16	15
October	IX	29	.45	0	—
	X	101	.47	0	—
	F_1	6	.55	19	7
1979					
June	IX	7	.78	—	—
	X	5	.80	—	—
	B_1	18	.76	—	—
July	IX	19	.78	77	83
	X	18	.72	62	47
	C_1	72	.58	26	97
August	IX	13	.73	65	37
	X	6	.68	52	13
	D_1	47	.72	62	124
September	IX	10	.59	29	14
	X	7	.58	26	9
	E_1	15	.58	26	20
October	IX	41	.62	37	65
	X	17	.61	34	26
	F_1	48	.64	42	83
November	IX	38	.57	24	50
	X	30	.65	44	54
	G_1	56	.57	24	74