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# Lake Powell Fisheries Investigations



1975-1979 Five-year Completion  
and 1979 (Segment 8) Annual Performance Report

for Colorado River Drainage and Tailwaters  
Dingell-Johnson project F-28-R

Utah Division of Wildlife Resources  
Publication Number 80-11

LAKE POWELL POSTIMPOUNDMENT INVESTIGATIONS

Completion Report

January 1975-December 1979

Annual Performance Report

January 1979-December 1979

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Puolication No. 80-11

Dingell-Johnson Project No. F-28-R-8

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## TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES . . . . .	iv
LIST OF FIGURES . . . . .	vi
INTRODUCTION . . . . .	1
JOB NUMBER	
I. THREADFIN SHAD STUDY . . . . .	3
Background . . . . .	3
Methods . . . . .	4
Results and Discussion . . . . .	8
Recommendations . . . . .	15
References . . . . .	16
II. MEASUREMENT OF FISHERIES HARVEST, PRESSURE AND SUCCESS . . . . .	18
Background . . . . .	18
Methods . . . . .	18
Results and Discussion . . . . .	19
Recommendations . . . . .	32
References . . . . .	33
III. INDEX TO ANNUAL FISH POPULATION TRENDS . . . . .	35
Background . . . . .	35
Methods . . . . .	35
Results and Discussion . . . . .	38
Annual Netting . . . . .	38
Electrofishing . . . . .	44
Recommendations . . . . .	48
References . . . . .	49
IV. STRIPED BASS CULTURE . . . . .	51
Background . . . . .	51
Methods . . . . .	52

# TABLE OF CONTENTS (continued)

	<u>Page</u>
Preseason Treatment . . . . .	52
Fertilization . . . . .	52
Filling . . . . .	52
Oxygen and Plankton Development . . . . .	53
Supplemental Fertilization . . . . .	53
Stocking of Fry . . . . .	53
Insect Control . . . . .	55
Vegetation Control . . . . .	55
Fry Food Habits . . . . .	56
Supplemental Feeding . . . . .	56
Harvest . . . . .	56
Results and Discussion . . . . .	57
Recommendations . . . . .	62
References . . . . .	64
V. EVALUATION OF STRIPED BASS INTRODUCTIONS . . . . .	65
Background . . . . .	65
Methods . . . . .	65
Results and Discussion . . . . .	66
Recommendations . . . . .	74
References . . . . .	75

# LIST OF TABLES

<u>Table</u>		<u>Page</u>
1.	Monthly water temperatures, measured from the surface to the bottom, during the winters of 1977-78 and 1978-79, at the three trawling locations . . . . .	14
2.	Estimated fishing pressure (angler days) by access area and month, Lake Powell, March-September 1979 . . . . .	21
3.	Fishing boat use by month and year at Lake Powell, 1975-79. Numbers represent total fishing boats using lake/month. Also given are the average time (hr) fished/trip (H/T) and the mean number of fishermen/boat (F/B) . . . . .	23
4.	Catch rates (fish/angler hr) by species and access area, Lake Powell, March-September 1979 . . . . .	26
5.	Catch rates (fish/angler hr) by species and month, Lake Powell, March-September 1979 . . . . .	27
6.	Species composition by percent of the total recorded creel, Lake Powell, 1975-79 . . . . .	31
7.	Number of fish caught in gill nets (30 net-days/station), Lake Powell, March 1979 . . . . .	39
8.	Catch rate (fish/net-day) of fish caught in gill nets, Lake Powell, March 1979 . . . . .	40
9.	Catch rate by species and year, annual gill netting, Lake Powell, 1971-79 . . . . .	43
10.	Mean catch rate (fish/hr) of fish caught by electrofishing, Lake Powell, August-September 1979 . . . . .	45

# LIST OF TABLES (continued)

<u>Table</u>		<u>Page</u>
11.	Fingerling survival and total production of culture ponds, 1974-79 . . . . .	58
12.	Production/ha during 1979 culture season . . . . .	58
13.	Food habits of 13-day-old fry during 1978, the most productive culture season . . . . .	61
14.	Striped bass stocking history of Lake Powell . . . . .	67
15.	Average catch/seine haul of young-of-the-year striped bass introduced into Wahweap Bay, 1975-1979 . . . . .	69
16.	Back calculated growth in total length (mm) of Lake Powell striped bass from 1975-79 . . . . .	70
17.	Comparison of growth rates of striped bass from various studies. All data converted to total length (mm) . . . . .	71
18.	Food habits, by season, of striped bass collected in Lake Powell from 1975-79 . . . . .	73

# LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1.	Echograms showing random distribution of threadfin shad at night and schooling behavior during the day . . . . .	5
2.	Lake Powell, showing trawling locations (dots) . . . . .	7
3.	Mean number of young-of-the-year shad captured/ trawl haul at Bullfrog . . . . .	10
4.	Mean number of young-of-the-year shad captured/ trawl haul at Hite . . . . .	11
5.	Mean number of young-of-the-year shad captured/ trawl haul at Wahweap . . . . .	12
6.	Residence of anglers using Lake Powell, 1975-79 . . . . .	22
7.	Indices of total recreational boat use and angling pressure, Lake Powell, 1965-79 . . . . .	24
8.	Catch rates (fish/angler hr) for largemouth bass, black crappie and all species during the months of April-June, 1965-79, Lake Powell . . . . .	28
9.	Map of Lake Powell, Utah-Arizona, showing annual netting sites (dots) and electrofishing transects (circles) . . . . .	36
10.	Catch rates (fish/net-day) of largemouth bass and walleye from annual netting, 1971-79, Lake Powell . . . . .	41
11.	Mean number of young-of-the-year largemouth bass and black crappie collected/hr of electrofishing during August-September 1977-79, Lake Powell . . . . .	46
12.	Timing of fry introductions in relation to relative abundance of small plankters in the most productive ponds from culture seasons, 1975-79. Fingerling production/ha is listed in brackets . . . . .	60

## INTRODUCTION

Fisheries investigations on Lake Powell began in 1963, shortly after impoundment and have continued to the present. The initial work included physical and chemical descriptions of the filling reservoir, plankton development, life history studies of introduced game fish, and an estimation of fishing pressure and success. These studies were funded, in part, by federal monies provided under Section 8 of Public Law 485, the Colorado River Storage Project Act, and were completed in 1971.

Important events that have occurred since the initial introduction of largemouth bass (Micropterus salmoides), black crappie (Pomoxis nigromaculatus) and rainbow trout (Salmo gairdneri), include the introduction of threadfin shad (Dorosoma petenense) in 1968, and the steadily increasing walleye (Stizostedion vitreum vitreum) population which developed from stock present in the drainage before impoundment. Threadfin shad were introduced to provide forage for all game fish and to allow introduction of striped bass (Morone saxatilis). Striped bass were introduced in 1974 after shad were permanently established.

New studies undertaken since 1971, included an annual netting program to determine trends in game fish population dynamics; fish food supplies and utilization; threadfin shad population dynamics and predator impact; striped bass culture and evaluation of striped bass introductions. The study of fishing pressure and success has been on going since 1963, while the study of the physical and chemical nature of Lake Powell was completed in 1974.



Findings of our research from January 1975 to December 1979, are given in this report along with detailed results of the 1979 sampling year. More detailed accounts of events occurring in any particular year, 1975 to 1978, can be found in Lake Powell annual progress reports for that year (Hepworth et al. 1976; Hepworth et al. 1977; Hepworth et al. 1978; and Gustaveson et al. 1979). Lake Powell investigations since 1971 have been funded, in part, by Federal Aid to Fish and Wildlife Restoration, Project F-28-R, and by the Utah Division of Wildlife Resources.

## THREADFIN SHAD STUDY

## JOB I

Background

Threadfin shad were first introduced into Lake Powell in 1968. Shad are the predominant food item of all major game species (Hepworth and Gloss 1976; and May et al. 1975). They are typically pelagic and not readily sampled with conventional entrapment gear. The major objective of this study was to develop, through midwater trawling, an adequate system for sampling threadfin shad. The development of a midwater trawling system was completed in 1976. Data collected from 1976-79 were used to determine shad population indices and monitor monthly and annual population fluctuations. Information was also obtained on shad spawning periodicity.

Striped bass, a pelagic predator, were introduced into Lake Powell in 1974 and utilized the dense shad population in the open water areas of the reservoir. Previously established game species were usually confined to the littoral zones of Lake Powell. Threadfin shad population data collected from 1976-79 form a baseline for future comparisons in determining possible impacts of the expanding striped bass population on threadfin shad abundance.

## Methods

A 8.53 m steel hulled work boat was used for trawling. Two Marco W050 hydraulic winches powered by Vickers hydraulic pumps were run directly from the boat's inboard engines. With dual controls, it was possible to run both winches in tandem or individually. The trawl was designed after that described by von Geldern (1972). It measured 3.05 m square at the mouth, 15.24 m long with bar mesh net tapering from 20.4 cm in the throat to 0.32 cm at the cod end. The trawl was held open by a pair of depressors and hydrofoils attached at the the corners of the mouth. Galvanized wire rope cables (0.48 cm diameter) running from each winch were used in deploying and retrieving the trawl.

A standard tow was developed and used to permit consistent sampling and replication. During each tow, the boat was operated at 1,100 rpm's (1.6 m/sec) while 45.72 m of cable was played out and immediately retrieved. The average volume of water sampled was 3,178.44 m<sup>3</sup> and the maximum depth fished was approximately 10.7 m. The oblique tow allowed equal sampling of the water column from the surface to maximum depth rather than sampling shad from any one depth. For consistency, sampling was done at night when shad were distributed in a dense and uniform layer in the epilimnion rather than grouped in schools as found during the day (Figure 1) (Houser and Dunn 1967; and Netsch et al. 1971). Sample nights were during the period between new moon and first quarter to ensure dark nights and eliminate variability caused by moonlit nights.

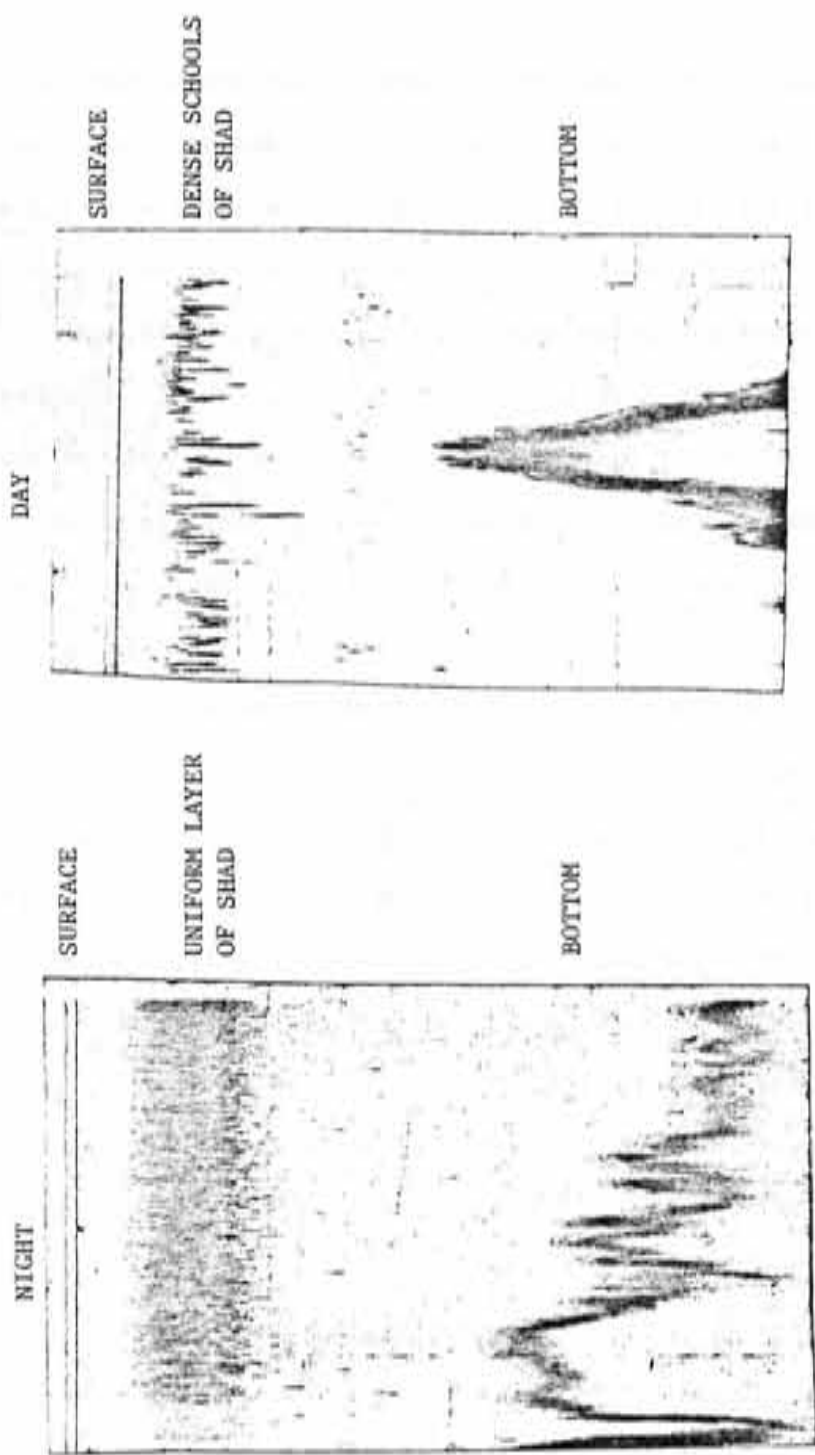


Figure 1. Echograms showing random distribution of threadfin shad at night and schooling behavior during the day.

Trawling locations were selected to sample lake areas near the dam, midway uplake and near the Colorado River inlet at Wahweap, Bullfrog and Hite, respectively (Figure 2). Each trawling location was sampled one night/month. Wahweap, Bullfrog and Hite were sampled on consecutive nights to allow comparison under approximately similar times and conditions. Four standard tows were made each sample night. Lighted buoys, permanently fixed in position, were used to mark trawl transects.

Each night before trawl samples were taken, an 8-minute sonar transect was run over the trawling course. The sonar unit, which was also used to generate the echograms of Figure 1, was a Simrad Skipper Sounder Model E3. The boat was operated on one engine at 800 rpm's during the sonar run.

The trawl selectively captured larval and juvenile shad. Adults were taken infrequently. Larval and juvenile shad were differentiated by total length after criteria presented by Barnes (1977). Larval shad were designated as shad smaller than 25 mm total length while juveniles were considered to be between 25 mm and 50 mm. All shad collected were immediately preserved in a 10% formalin solution. Number of shad, weight of catch, average weight, average total length and range were determined for each haul.

Monthly temperature profile data were collected at each trawling location using an ARA Model FT-2 electronic thermometer. Temperatures were measured at 0.3 m intervals between the surface and 30.5 m.

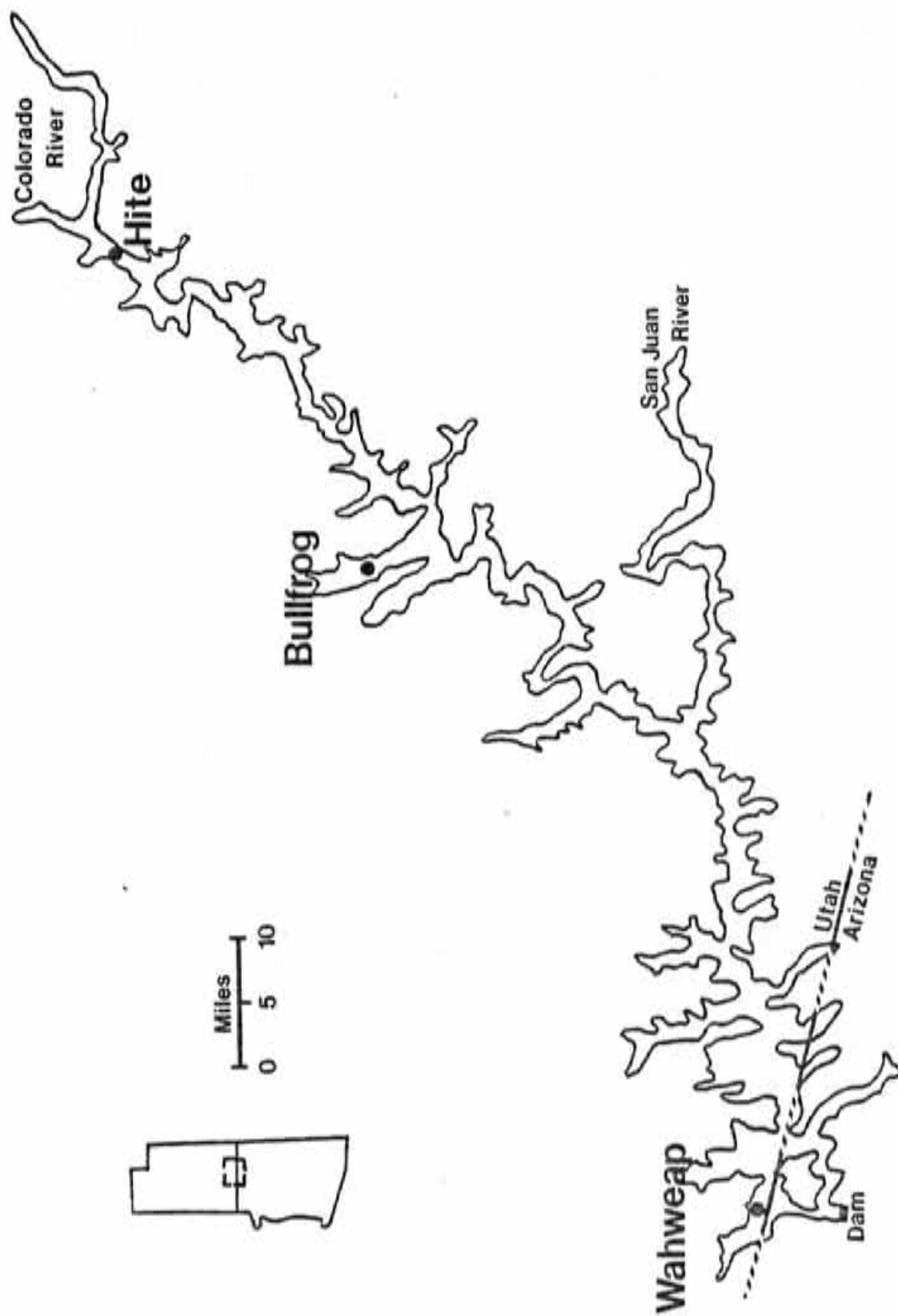


Figure 2. Lake Powell, showing trawling locations (dots).

## Results and Discussion

Threadfin shad have been stocked throughout the southwest as forage (Burns 1966; LaRivers 1962; Kimsey et al. 1957; and Beers and McConnell 1966). Shad were introduced into Wahweap Bay, Lake Powell in June 1968 (Miller et al. 1969). Approximately 90% of the original plant were young-of-the-year. Sampling in the winter of 1968-69 revealed the shad had spawned the first summer. Heidinger and Imboden (1974) found that young-of-the-year shad planted into a shad-free environment matured and spawned the same year. Threadfin shad in Lake Powell had spread to Hall's Crossing, 161 km uplake, by the summer of 1969 and were reservoirwide by the summer of 1970 (Gloss et al. 1971).

Many studies have revealed shad spawning more than once a year. Two spawning peaks were observed in California ponds in 1955, and Lake Havasu, California-Arizona in 1956 (Kimsey 1958; and Kimsey et al. 1957). Threadfin shad stocked in Hawaii spawned from June through September (Hida and Thompson 1962).

In Lake Powell, shad generally began spawning in early May at Hite, mid-May at Bullfrog and by late May in Wahweap Bay. This was similar to the progressive spawning pattern reported by Netsch et al. (1971) in Beaver Reservoir, Arkansas. Most years, spawning continued at Lake Powell throughout the summer and into the fall. With the exception of 1979, larval shad were collected annually at Wahweap until September. Larvae were found at Bullfrog in September 1977, and at Hite the first week of October 1978. No larval shad were found at any location after July 1979.



Hepworth et al. (1978) reported two spawning peaks at Bullfrog (Figure 3) and Hite (Figure 4) in 1977. Apparently, there were two spawning peaks at Bullfrog in 1979. A plot of the mean catch of young-of-the-year shad/trawl tow at Bullfrog revealed a population oscillation identical to that recorded in 1977 (Figure 3).

All three trawling locations have shown a great deal of population fluctuation (Figures 3, 4 and 5). Threadfin shad populations appeared to be building until 1978. In 1979, young-of-the-year production dropped drastically below 1978. The highest number of young-of-the-year shad collected per tow at Wahweap was only 34. Catch/tow at Hite was also depressed while catch values at Bullfrog were only slightly below 1977.

With only three years data at Bullfrog and Hite and 3 1/2 years data at Wahweap, it is not clear what normal population fluctuations should be expected. Anderson (1973) found spawning was affected by density dependent factors, including crowding and nutritional conditions. It is possible that the Lake Powell shad population had reached a point where crowding affected the normal development of eggs and sperm, and many adults did not spawn in 1979. Shad were not observed spawning at any location, although eggs were found on floating debris at Hite on 4 June 1979. In previous years, spawning adults were observed at dawn in the Wahweap and Bullfrog marinas.

The food supply appeared to be adequate in the Wahweap area near the end of May since large numbers of plankton were collected in meter-net tows at that time.



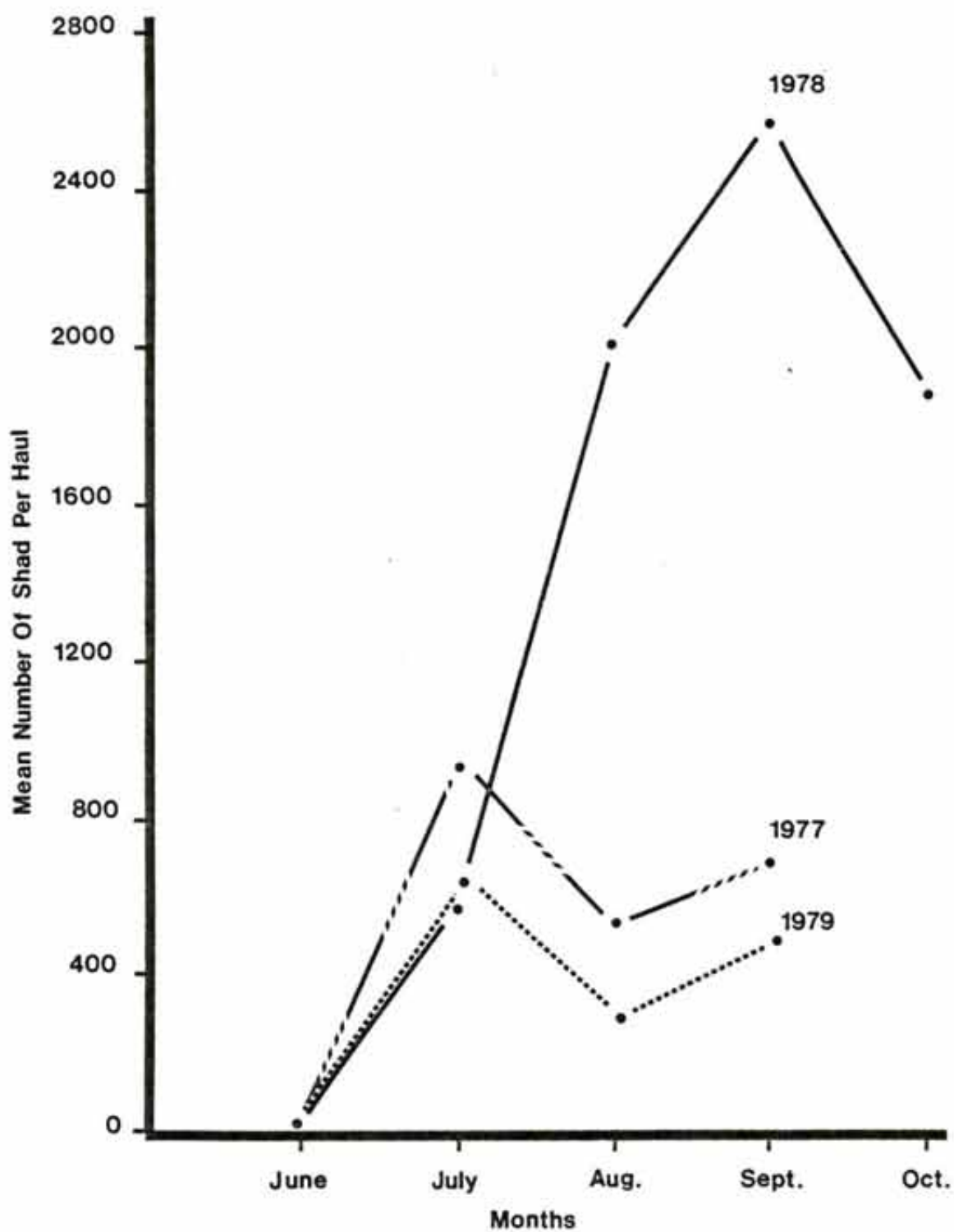


Figure 3. Mean number of young-of-the-year shad captured/trawl haul at Bullfrog.

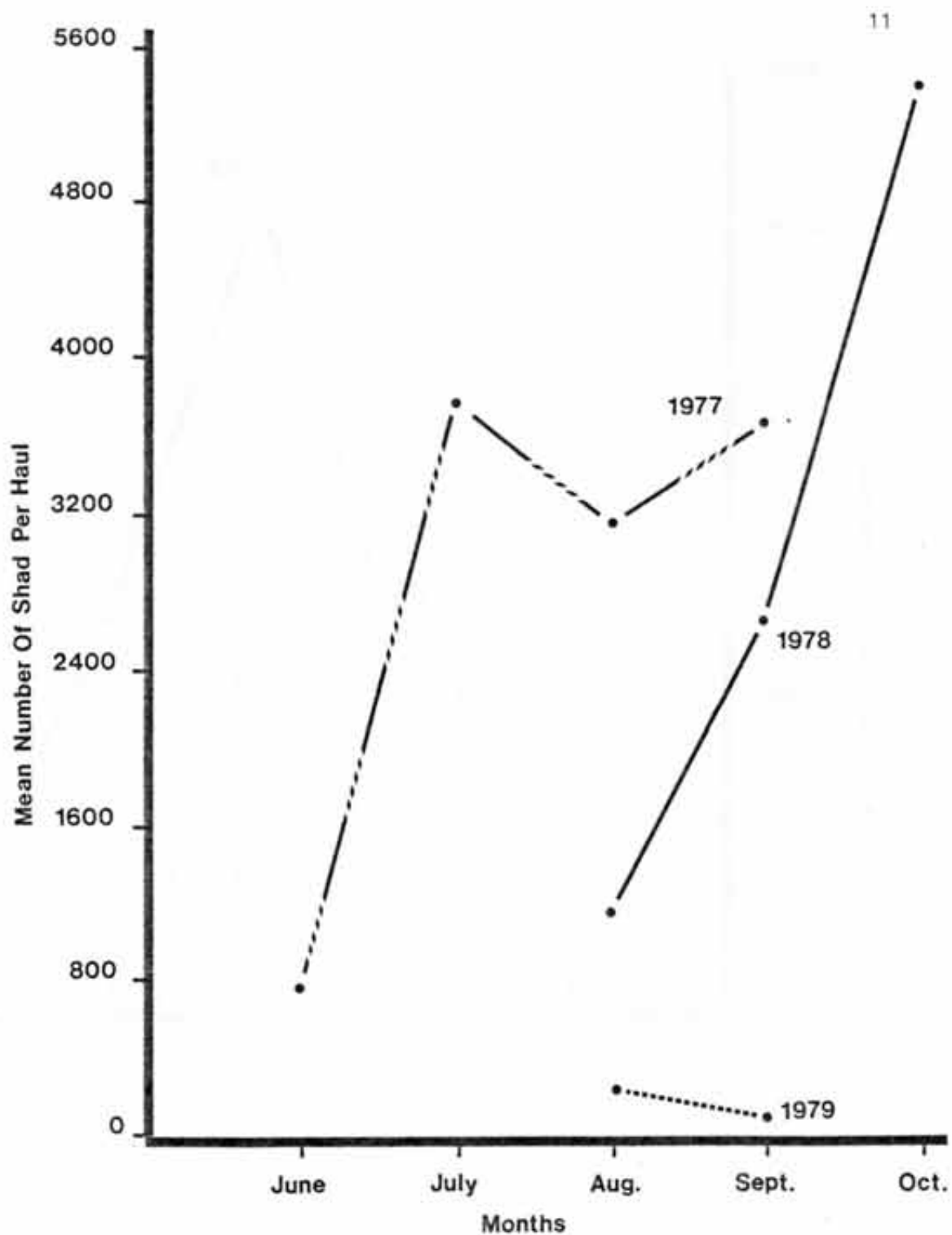


Figure 4. Mean number of young-of-the-year shad captured/trawl haul at Hite.

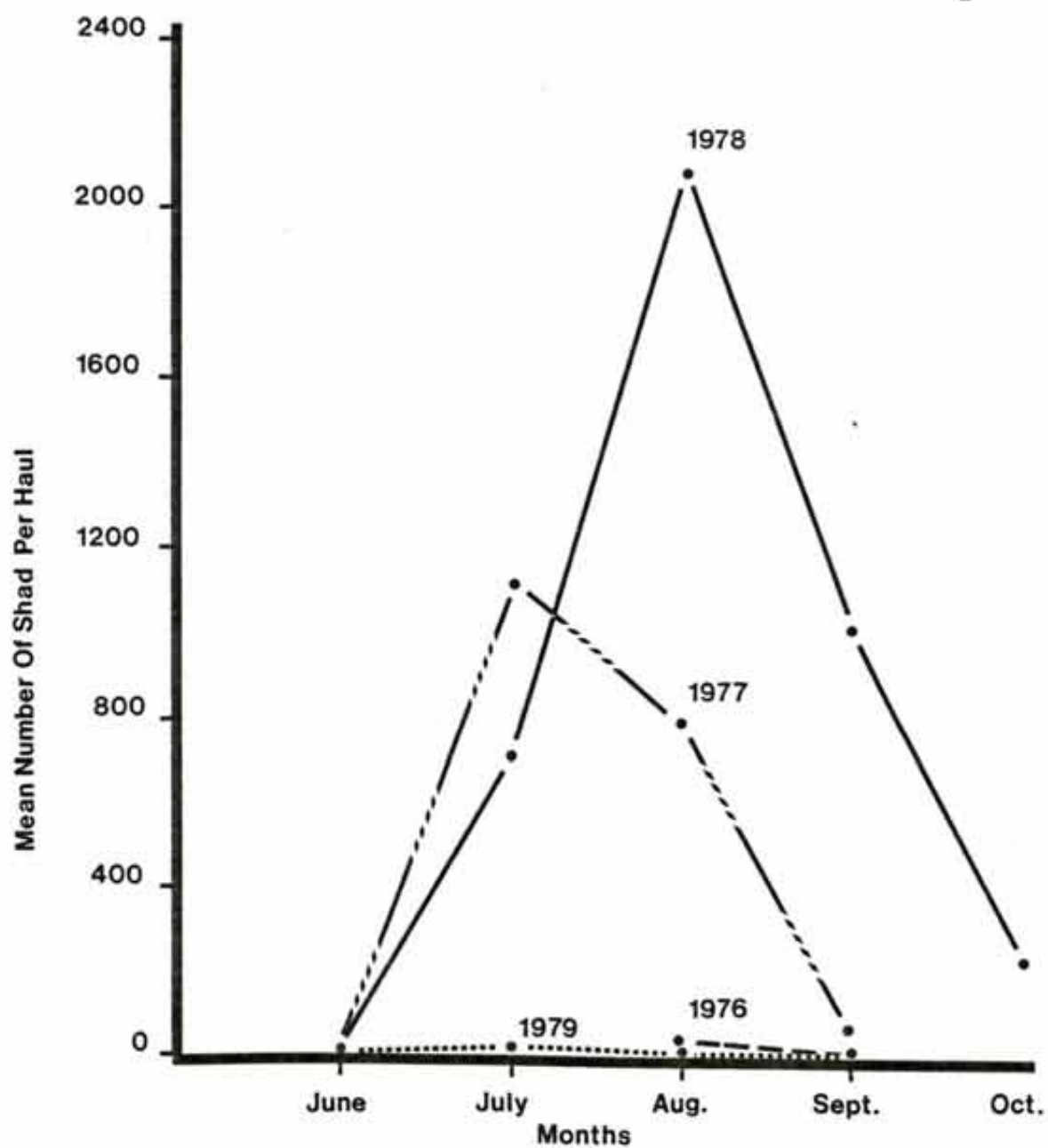


Figure 5. Mean number of young-of-the-year shad captured/trawl haul at Wahweap.

Threadfin shad are very susceptible to low water temperatures and winter mortality. Parson and Kimsey (1954) observed high mortalities at 7.2 C. Griffith (1978) tested thermal tolerances of threadfin shad in the laboratory and found a reduction in feeding at 10 C, and at 6.1-6.7 C, shad became unresponsive to movements and vibrations around them. Laboratory shad began dying at 8.9 C. Strawn (1965) observed a 50% loss at 6.1 C. Hubbs (1951) found shad dying at 11.7-13.9 C after a sudden cold period.

The winter of 1978-79 was the coldest on record since the establishment of Lake Powell. Air temperatures dropped suddenly the first week of December 1978, when nighttime temperatures fell to near -17.8 C and daytime temperatures were only -10 to -5 C. The weather moderated only slightly through February 1979. A comparison of winter water temperatures (Table 1) revealed that water temperatures at Hite reached critical levels in February 1979, while temperatures at Bullfrog and Wahweap were marginal for shad survival. Water temperatures throughout the reservoir were near or below the critical 7.2 C temperature for most of the winter.

It appeared that shad lived through the coldest temperatures only to die as the water began to warm in March. Large numbers of shad were found dead at Hite early in March. Live shad were quite visible during the first week of March in the vicinity of Wahweap Marina. Hundreds of grebes were seen feeding on the shad at that time.

Table 1. Monthly water temperatures, measured from the surface to the bottom, during the winters of 1977-78 and 1978-79, at the three trawling locations.

Location	Temperatures (C)*			
	December		February	
	1977	1978	1978	1979
Wahweap	11.7-7.2	12.2-8.9	7.8-8.9	8.9-7.8
Bullfrog	12.2-9.4	11.1-8.9	8.3-7.2	7.8-5.6
Hite	12.8-8.9	10.6-5.6	8.9-6.1	6.7-3.3

\*Temperatures were measured monthly by the Water and Power Resources Service using an electronic thermometer.

A large adult population resulting from very high production in 1978 may have created a high density situation resulting in reduced development of eggs and sperm. Also, stress from the cold winter temperatures may have inhibited normal sexual development. One or both of these situations could have been responsible for low young-of-the-year shad production in 1979 and the detection of only one spawning peak at Wahweap and Hite. Assuming the 1979-80 winter does not produce abnormally low temperatures, the lower density of shad should allow normal sexual development and the population should start to rebuild in 1980.

Any possible impacts of striped bass on threadfin shad have been overshadowed by the extreme annual fluctuations in the shad population. The information collected from 1975-79 will be used for future comparisons.

Recommendations

Continue monthly trawl sampling as presently conducted to obtain data comparable with that collected during this reporting period. This information is essential for detection of lasting trends wrought by predation, reservoir aging and temperature.

Establish a sampling scheme for assessing the magnitude of the overwintering population of adult shad. Options include sonar transects prior to spawning in conjunction with entrapment gear.

Monitor winter water temperatures to detect the occurrence of critical temperatures that may affect shad survival, then assess the effects these temperatures have on the shad population.

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## MEASUREMENT OF FISHERY HARVEST, PRESSURE AND SUCCESS

## JOB II

Background

Angler use and success rates have been estimated annually at Lake Powell, beginning soon after impoundment (Stone 1965, 1966, 1967, 1971 and 1972; Stone and Rathbun 1968 and 1969; Rathbun 1970; Gloss et al. 1974; May and Hepworth 1976; Hepworth et al. 1976, 1977 and 1978; and Gustaveson et al. 1979a). In general, both total recreational boat use and angling pressure have increased steadily since 1965. Angler success has varied over the history of the reservoir with the best fishing occurring in the early 1970s. Black crappie and largemouth bass have consistently comprised over 70% of the annual catch since 1970. Striped bass and walleye have recently shown signs of developing into significant sport fisheries. A detailed review of fishing pressure and success on Lake Powell for 1964-1976 is given by Gustaveson et al. (1979b).

Methods

A scheduled creel census was conducted from March through September in 1975, 1978, 1979 and from April through September in 1977. During 1976, the census was conducted during the three months of most intensive angler use--April through June. The majority of angling activity (over 80%) at Lake Powell occurs from March through September (May and Hepworth 1976).

Creel clerks censused boats as they returned to launching ramps at the four major access areas--Wahweap, Hall's Crossing, Bullfrog and Hite. Due to the isolated nature of the reservoir and limited access, almost all anglers gain access at one of these four points. Fishing pressure by shore anglers was considered negligible. The Wahweap access was censused an average of 10 days/month, while a total of 5-13 days/month were spent censusing anglers at Hall's Crossing, Bullfrog and Hite. Approximately 50% of the census days for each access area were weekends or holidays with weekdays making up the remaining half. Data obtained during interviews of anglers included the number and species of fish caught, length of trip, actual time spent fishing, number of anglers/boat and residence of anglers. Total length measurements, scales and stomach samples were also obtained from selected samples of game fish.

Estimates of angling pressure were based on (1) the total (fishing and nonfishing) number of boat days; (2) the percentage of total boat days which included angling activity; and (3) mean number of anglers/fishing boat. The latter two parameters were estimated for each month and access area from angler interviews. Estimates of total boat days were taken directly from National Park Service (NPS) boat use figures. NPS estimates of boat days for a given month were the sum of daily instantaneous counts (made at 1:00 p.m.) of empty boat trailers at launching ramps and docking areas.

### Results and Discussion

A total of 2,948 boating parties were censused by clerks in 1979, with 959 (32.5%) of these reporting angling activity. The average boat day for anglers was 7.1 hr long. Anglers spent an average of 4.5 hr

fishing/boat day. There was an average of 2.4 anglers in each fishingboat. The estimated angling pressure for the entire reservoir for March-September 1979 was 150,324 angler days (Table 2).

Wahweap received the most use of the four major access areas. Total recreational boat use at Bullfrog was almost as great while angler use there was much lower. Boaters at Hall's Crossing accounted for 16.4% of the total boat use for 1979 and 22.4 % of the angling pressure from March-September. Although only 8.9% of the total boat days for the reservoir were recorded for anglers gaining access at Hite, 18.1% of the angler days were recorded for boaters there.

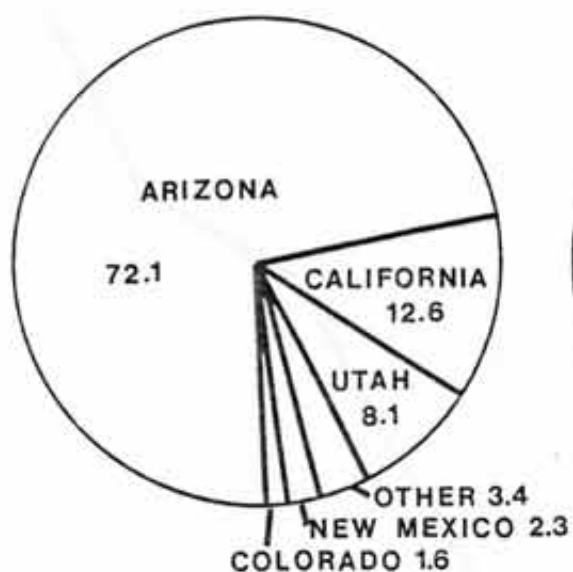
The majority of anglers fishing at Lake Powell during the 1979 census period were from Utah, Arizona or Colorado. Utah and Colorado accounted for almost all of the anglers censused at Bullfrog and Hite. Colorado and New Mexico were given as the residence of more than 80% of the anglers at Hall's Crossing, while most of the anglers interviewed at Wahweap were from Arizona. Figure 6 illustrates the residence of anglers at Lake Powell for the years 1975-79.

Fishing boat use as well as total recreational boat use in 1979 increased from 1978 (Table 3 and Figure 7). Indices for angling pressure and total recreational boat use both increased at Wahweap, Hall's Crossing and Hite; the number of boaters and anglers at Bullfrog decreased in 1979. One reason for the overall increase in use in 1979 may have been the improved rate of success for anglers after two years of relatively poor fishing. The 2,284 anglers censused in 1979 spent a total of 9,979 hr fishing and caught 4,523 fish for an overall success rate of

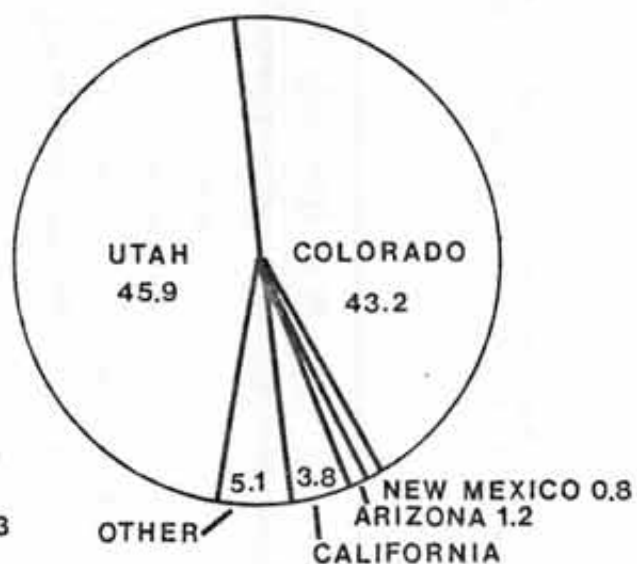
Table 2. Estimated fishing pressure (angler days) by access area and month, Lake Powell, March-September 1979.

Month	Wahweap	Bullfrog	Hall's	Hite	Total	%
March	3,395	1,739	2,258	1,003	8,395	5.6
April	11,358	7,020	5,058	5,986	29,422	19.6
May	16,405	6,990	8,232	5,627	37,254	24.8
June	10,135	2,840	4,523	3,669	21,167	14.1
July	10,187	2,098	2,638	2,319	17,242	11.5
August	6,041	1,229	7,386	2,623	17,279	11.5
September	5,873	4,166	3,580	5,946	19,565	13.0
Total	63,394	26,082	33,675	27,173	150,324	

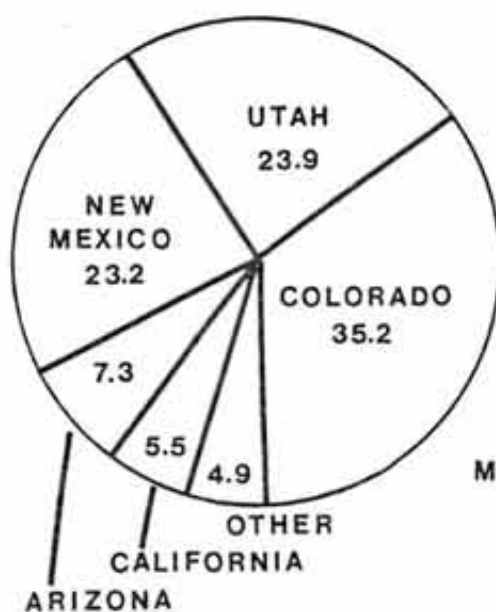
## WAHWEAP



## BULLFROG



## HALLS



## HITE

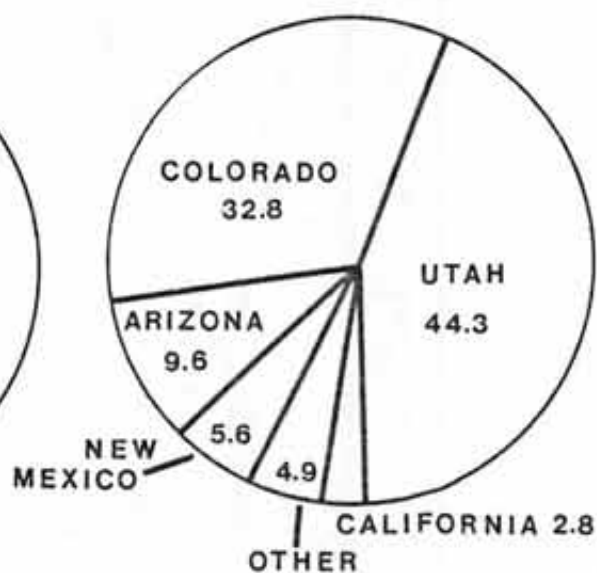


Figure 6. Residence of anglers using Lake Powell, 1975-79.

Table 3. Fishing boat use by month and year at Lake Powell, 1975-79. Numbers represent total fishing boats using lake/month. Also given are the average time (hr) fished/trip (H/T) and the mean number of fishermen/boat (F/B).

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	H/T	F/B
1975	443	1,237	4,364	9,770	11,265	7,322	3,100	2,503	3,432	3,404	1,546	344	48,730	4.5	3.0
1976	593	1,300	4,572	12,776	15,137	8,642	5,354	5,655	4,460	4,021	1,853	384	64,747	3.8	2.8
1977	251	1,602	3,327	12,772	15,501	10,168	4,957	4,640	6,700	4,960	1,634	326	66,838	3.3	2.9
1978	290	669	3,118	12,877	10,597	8,499	4,986	4,640	5,174	4,693	2,332	965	58,840	3.1	2.4
1979	340	407	3,849	12,257	14,390	8,784	6,914	8,085	8,242	5,709	1,811	684	71,472	4.5	2.4
Ave.	383	1,043	3,846	12,090	13,378	8,683	5,062	5,105	5,602	4,557	1,835	541	62,125	3.8	2.7
$\bar{x}$	0.6	1.7	6.2	19.5	21.5	14.0	8.1	8.2	9.0	7.3	3.0	0.9			

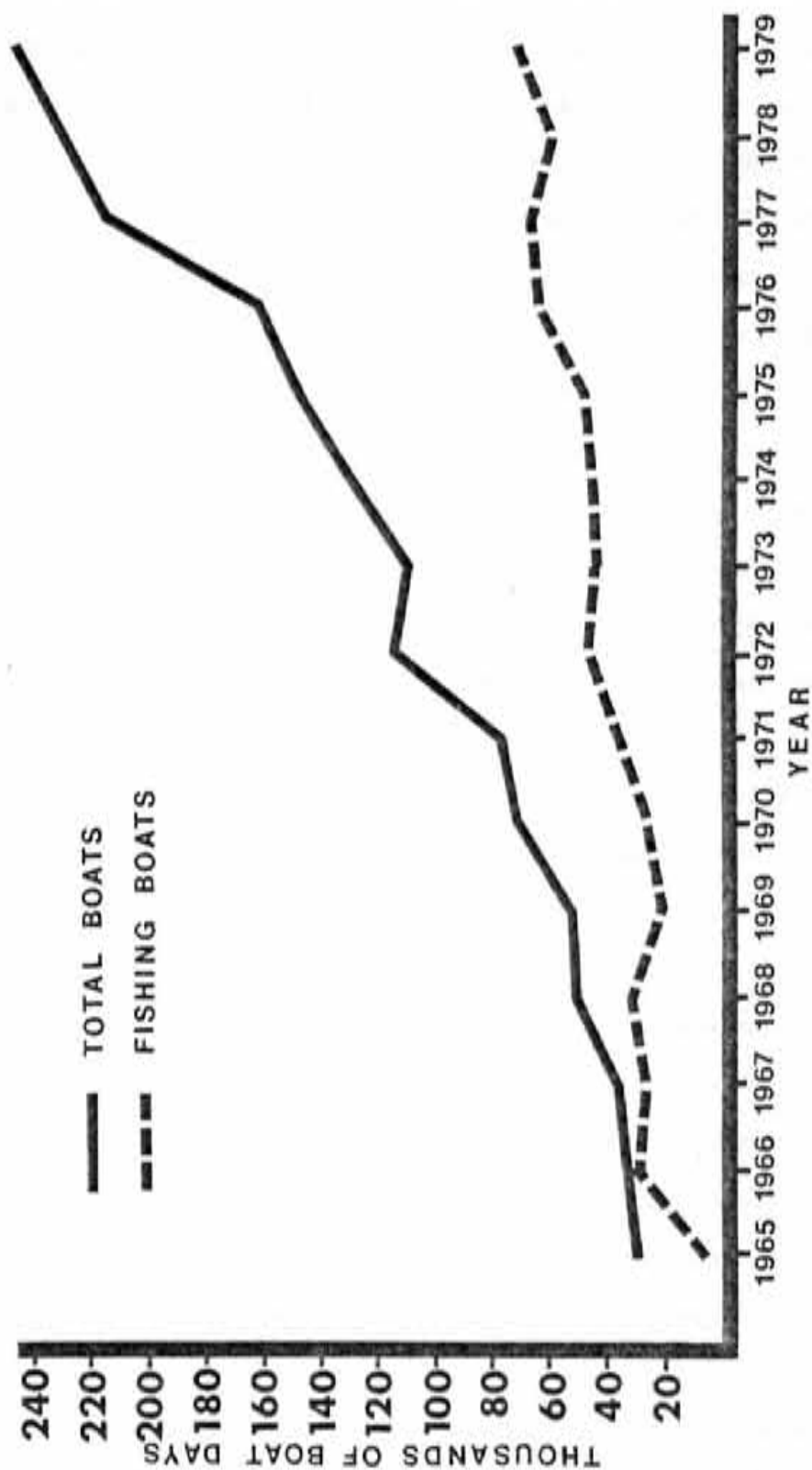


Figure 7. Indices of total recreational boat use and angling pressure, Lake Powell, 1965-79.



0.45 fish/angler hr. Success rate was highest for anglers censused at Wahweap (Table 4), followed by Hite and successively lower at Bullfrog and Hall's Crossing. Success rates also varied by month (Table 5). Fishing was best during April and May when anglers (all areas combined) creeled fish at a rate of 0.54 fish/angler hr.

Largemouth bass were caught more often than other species in 1979, comprising 48.4% of the catch. Black crappie accounted for 35.5% of the total harvest. Catch rates (all areas combined) for largemouth bass and black crappie for the 1979 census period were 0.22 and 0.16 fish/angler hr, respectively. Catch rates for these two species showed an improvement for the first time since 1975 (Figure 8). For the three months of most intensive angling (April-June), the catch rates for largemouth bass and black crappie were about double the rates for the same months in 1978. Channel catfish made up 6.1% of the harvest in 1979, being creeled at rates up to 0.10 fish/angler hr during the warmer summer months. Striped bass were caught at an overall rate of 0.02 fish/angler hr and comprised 3.4% of the harvest.

Many factors influence angling success rates, including the absolute numbers of catchable-sized game fish available and the vulnerability of the available fish to anglers. The former category includes spawning success and recruitment (year-class strength), and interactions (competition, predation, etc.) among sympatric species. Factors affecting the vulnerability of available fish to anglers include weather conditions, fish behavior, and angler techniques and skill. Indices of abundance (see Job III) for catchable-sized largemouth bass have shown no correlation with angler success at Lake Powell in the past. The same



Table 4. Catch rates (fish/angler hr) by species and access area, Lake Powell, March-September 1979.

Species	Wahweap	Bullfrog	Hall's	Hite	Mean <sup>a</sup>
Largemouth bass	0.28	0.09	0.15	0.30	0.22
Black crappie	0.18	0.23	0.05	0.07	0.16
Channel catfish	0.03	t <sup>b</sup>	0.04	0.04	0.03
Bluegill	0.02	0.01	0.01	0.02	0.02
Rainbow trout	t	0.00	0.00	0.00	t
Walleye	t	0.01	t	t	t
Striped bass	0.03	t	t	0.00	0.02
Total	0.55	0.35	0.26	0.43	0.45

<sup>a</sup>Total catch divided by sum of angler hr.

<sup>b</sup>Less than 0.01 fish/angler hr.

Table 5. Catch rates (fish/angler hr) by species and month, Lake Powell, March-September 1979.

Species	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Mean <sup>a</sup>
Largemouth bass	0.35	0.25	0.19	0.18	0.02	0.09	0.08	0.22
Black crappie	0.06	0.28	0.26	0.06	0.02	0.02	t	0.16
Channel catfish	t <sup>b</sup>	t	0.04	0.07	0.07	0.10	0.04	0.03
Bluegill	0.00	0.01	0.04	0.03	0.03	0.03	0.05	0.02
Rainbow trout	t	t	t	0.00	0.00	t	0.00	t
Walleye	t	t	t	0.05	0.02	0.01	0.01	t
Striped bass	0.00	t	0.01	0.04	0.05	0.06	0.05	0.02
Total	0.41	0.54	0.54	0.43	0.20	0.31	0.24	0.45

<sup>a</sup>Total catch divided by sum of angler hr.

<sup>b</sup>Less than 0.01 fish/angler hr.

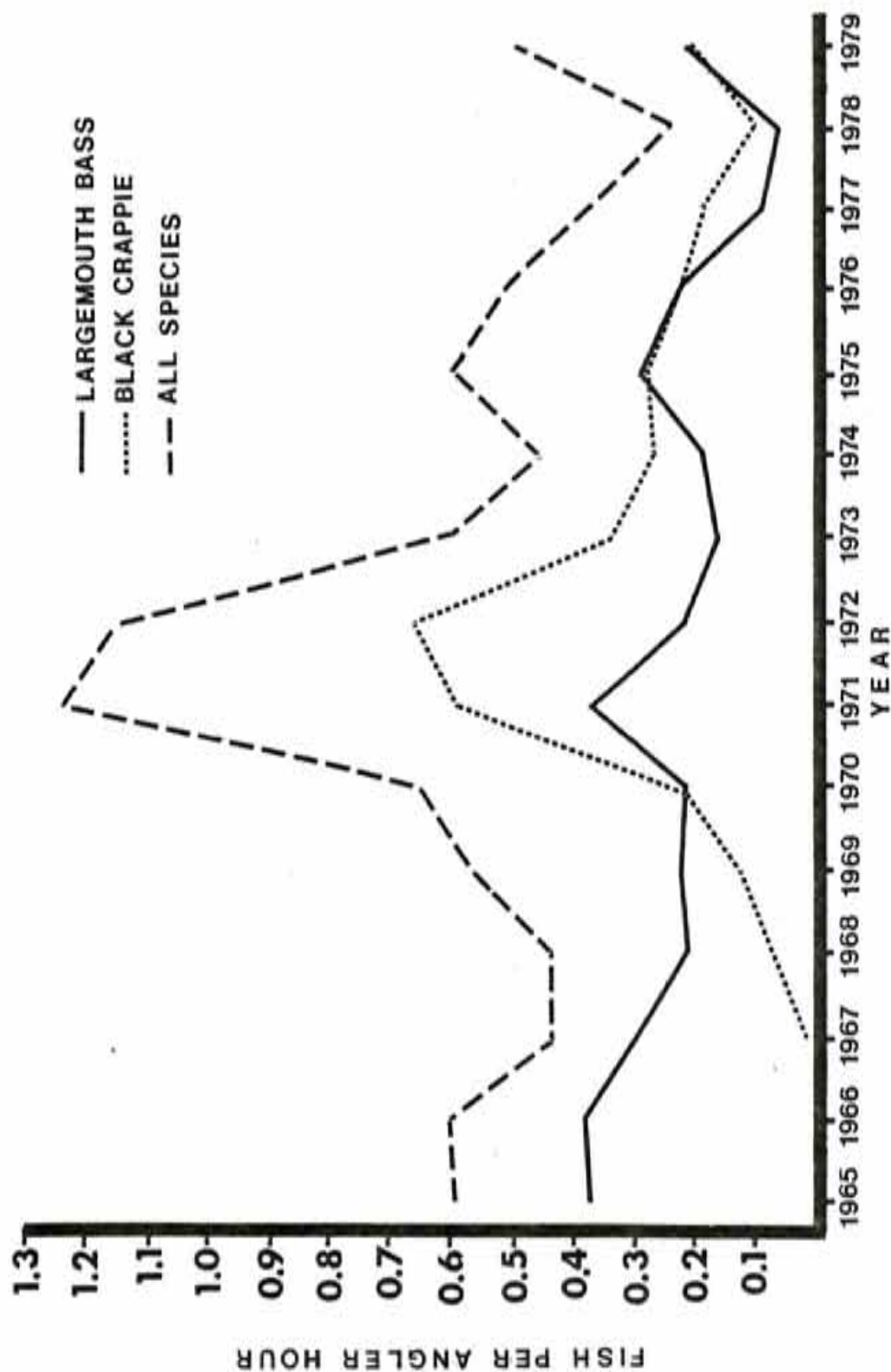


Figure 8. Catch rates (fish/angler hr) for largemouth bass, black crappie and all species during the months of April-June, 1965-79, Lake Powell.

phenomenon continued in 1979 when the angler success rate for bass more than doubled from 1978, while the numbers of largemouth bass caught during the annual gill netting decreased by about 30%. Factors besides those which affect only the absolute numbers of largemouth bass are apparently influencing angler success rates at Lake Powell. One such factor during 1978-79 may have been the decrease in the numbers of forage fish available to game fish (see Job I) and resulting changes in feeding behavior. Since game fish in Lake Powell feed almost exclusively on threadfin shad (Hepworth and Gloss 1976; and May et al. 1975), the dramatic change in shad density and biomass may have been reflected in an increased vulnerability of game fish to angling. This hypothesis is supported by the data for anglers at Wahweap. In recent years, anglers gaining access there usually had the lowest success rate of the four access areas. In 1979, however, anglers at Wahweap had the highest success rate on the reservoir. At the same time, the numbers and biomass of threadfin shad at Wahweap showed the most dramatic decrease among the areas sampled by trawling. Anderson and Heman (1969) reported differences in vulnerability to angling related to differences in forage densities. They observed that largemouth bass from areas with low forage densities were more vulnerable to angling than fish from areas with higher forage densities. Rose (1949) observed the same phenomenon for walleye at Spirit Lake, Iowa. High catch rates of walleye were usually associated with years featuring weak year classes of yellow perch, the main forage for walleye.

For the first time since impoundment, the catch rates of walleye and striped bass exceeded 0.01 fish/angler hr for more than half of the months of creel census. Striped bass made up approximately 30% of the

catch during July, August and September for anglers gaining access at Wauweap. The increased catch rates for both striped bass and walleye were likely a function of increases in absolute numbers of both species and the above-mentioned change in their forage base. In addition, the introduction of striped bass has resulted in a change in angler attitudes and techniques. More anglers became aware of the presence of striped bass and began using techniques that were conducive to taking these pelagic predators. Trolling open water areas became more common as anglers were rewarded with limit catches of striped bass. As more anglers used this technique in pursuit of striped bass, the catch of walleye also increased because walleye are more susceptible to anglers who troll deeper strata than to anglers who fish shallow structure near shore in search of largemouth bass.

Other than the increased number of walleye and striped bass creeled, the species composition of the average angler's catch has not appreciably changed in the past five years (Table 6).

The logistics involved in obtaining a precise estimate of fishing pressure have presented a problem since creel census work began on the reservoir. Methods employed in the past have included attempts at complete counts of all boats launched over a 24-hr period and counts made from aircraft. More recently, pressure estimates have been made by adjusting counts of empty boat trailers at access areas as recorded by NPS personnel. The primary objective of estimating pressure at Lake Powell is to detect and describe changes in angler use over a given time period, especially in relation to changes in the reservoir fishery or management programs. Consequently, methods of estimating pressure

Table 6. Species composition by percent of the total recorded creel, Lake Powell, 1975-79.

Year	Largemouth Bass	Black Crappie	Channel Catfish	Bluegill	Walleye	Striped Bass	Other
1975	48	44	3	4	t	t	t
1976	42	47	2	7	t	t	t
1977	32	49	10	7	t	t	1
1978	38	40	12	7	t	1	t
1979	48	36	6	4	2	3	t
Mean	41.6	43.2	6.6	5.8	t	t	t

<sup>t</sup>Less than 1% of total.



should be consistent from year to year. Although the NPS total boat use figures are subject to a number of valid criticisms (counts are made at a high use time, the length of their "boat day" is not defined), they do provide consistent indices for purposes of describing relative changes in angler use. Adjustment factors have not proved to be statistically reliable enough to justify their use and, in fact, have tended to compound the problem.

#### Recommendations

It is recommended that the NPS data for total boating use, along with information obtained from angler interviews, continue to be used to estimate fishing boat days (NPS boat days x percentage of boats reporting angling activity) and angler days (fishing boat days x mean number of anglers per fishing boat).

In addition, it is recommended that an intensive creel census be conducted every other year rather than annually. On years of intensive study (1981 and 1983), the census would be conducted during April through September. During 1980, 1982 and 1984, a census conducted during the three months of greatest angling activity--April, May and June--would still provide a means of detecting changes in angling success and pressure.

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## INDEX TO ANNUAL FISH POPULATION TRENDS

## JOB III

Background

Logistical problems preclude estimates of absolute numbers of fish in large reservoirs. Indices of relative abundance, however, may be used in such instances to describe gross changes in fish population densities and species composition. Catches from standardized gill-net sampling (Moyle 1950; and Gooch 1977) and electrofishing (von Geldern 1971) have been used as measures of relative abundance. A program of annual standardized gill netting has been conducted at Lake Powell since 1971 (Gloss et al. 1974; May and Hepworth 1976; Hepworth et al. 1976, 1977, 1978; and Gustaveson et al. 1979). In general, past gill-net catches have been dominated by largemouth bass and walleye, with the numbers of walleye increasing since the early 1970s.

An annual program of electrofishing was initiated in 1977 to obtain information on the relative abundance of fishes which were inadequately sampled by gill nets, e.g., young-of-the-year largemouth bass and black crappie.

Methods

Gill-net sampling was conducted during March 1975-79, at Padre Bay, the San Juan arm between Cha and Trail canyons, Rincon and Good Hope Bay (Figure 9). Gangs of ten 30.5 m diving experimental gill nets (mesh sizes 25, 38, 51 and 76 mm) were fished for three consecutive days at

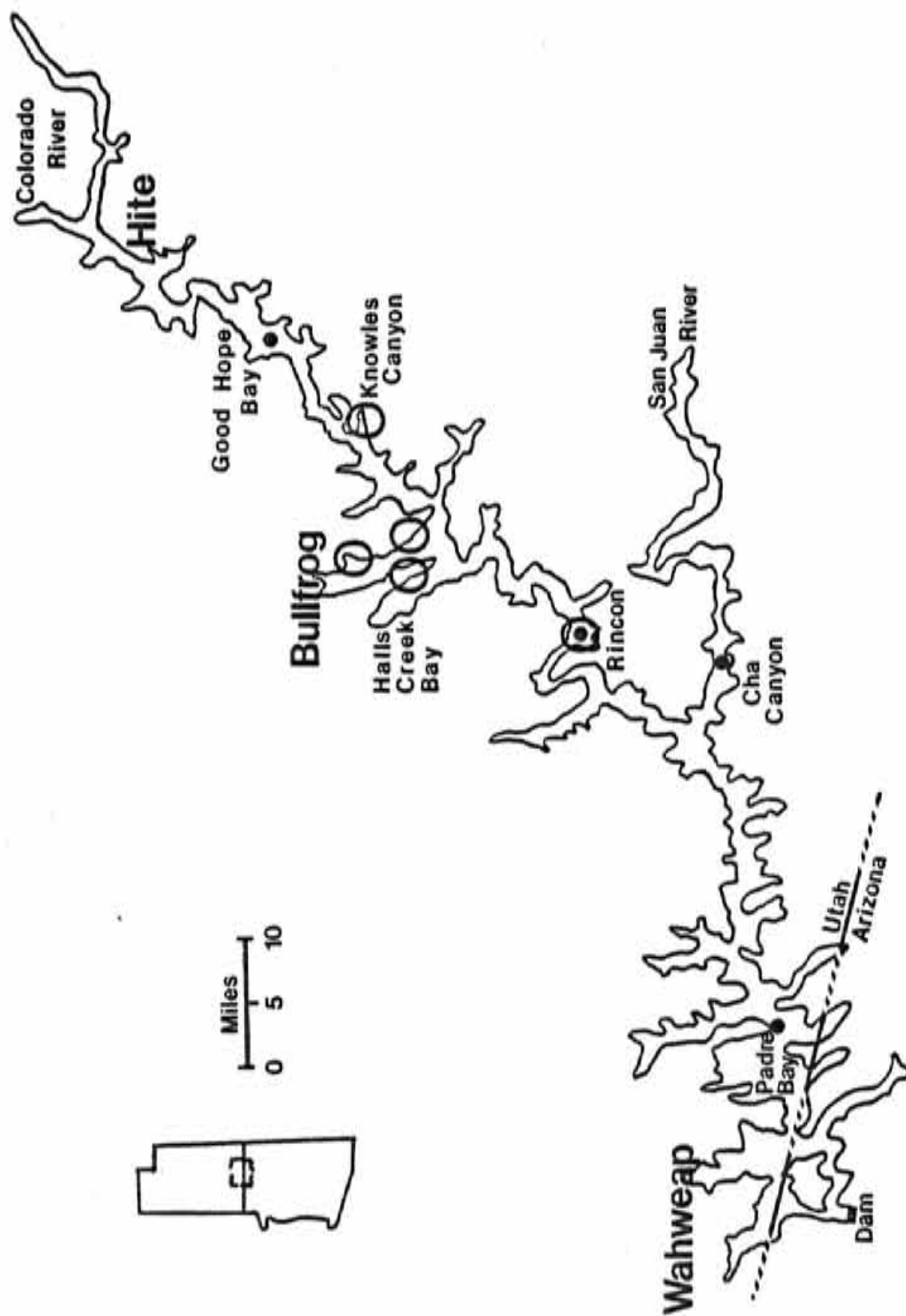


Figure 9. Map of Lake Powell, Utah-Arizona, showing annual netting sites (dots) and electrofishing transects (circles).

sizes 25, 38, 51 and 76 mm) were fished for three consecutive days at each station. On occasion, fewer nets were used due to equipment loss. Nets were set on the bottom and perpendicular to the shore in rock and rubble habitat with one end anchored at the shoreline. Fish were removed at 24-hr intervals, measured to the nearest millimeter (TL) and weighed to the nearest 5 g. Scales were taken from selected samples of all game fish for age and growth analysis.

The electrofishing boat was an 8.5 m Yukon Delta with fiberglass hull. An Onan 7.5 kw generator provided electrical power for the lighting system and a Coffelt Model RF-10 electroshocker. In 1977 and 1978, five 1.8 m long sections of 13 mm diameter cable, which hung from a bow-mounted boom, served as the positive electrodes. The negative electrode consisted of two 4.6 m long cables which trailed along both sides of the boat. Output of the electroshocker was 150-200 v dc, which was sequenced to the five positive electrodes so that each electrode was pulsed one time/second. In 1979, an electrode system similar to that described by Novotny and Priegel (1974) was used. The positive array consisted of two 1.0 m diameter hoops of EMT electrical conduit, each with seven to ten dropper electrodes. The negative electrode was increased to five 2.0 m long sections of cable on each side of the boat. The output to the entire positive array was 10-15 a and 150-200 v dc with a pulse rate of five/second. Water conductivities at the five transects ranged from 400-600 micromhos/cm. The sampling crew consisted of a boat driver and two netters. Sampling began after dusk and continued until the transect was covered, usually 2-6 hr. Five shoreline transects were sampled (Figure 9), including areas along the



midchannel of the lake, bays, and large and small side canyons. Each transect, except the Stanton Creek transect in Bullfrog Bay, was sampled twice in August-September 1977. All stations were sampled three times each at approximately one-week intervals in August-September during 1978 and 1979. Similar shoreline habitat was electrofished at each transect. All captured fish were measured to the nearest millimeter TL and released in the area of capture. The time of electroshocker operation was recorded and a catch rate was calculated for each species collected. The index of abundance for a given species and area was the mean of the catch rates for the three samples. Largemouth bass less than 175 mm TL and black crappie less than 125 mm TL were considered young-of-the-year.

#### Results and Discussion

Annual netting. In 1979, 733 fish were caught in 116 net-days (Tables 7 and 8). The highest catch rate was in Good Hope Bay, followed by Rincon, Padre Bay and the San Juan. The majority of the catch at each station consisted of largemouth bass and walleye. When catches from all stations were combined, largemouth bass accounted for 28.9% of the total and walleye for 51.4%. The combined catch rate of largemouth bass during 1979 was 31% lower than that recorded during the annual netting in 1978 (Figure 10). A decrease of about one bass/net-day occurred at Rincon, San Juan and Good Hope Bay. The catch rate of largemouth bass at Padre Bay remained about the same, one fish/two net-days. The overall catch rate for largemouth bass in 1979 was the lowest recorded since 1971. Walleye, on the other hand, were caught at the highest rate recorded since the annual netting program was initiated

Table 7. Number of fish caught in gill nets (30 net-days/station), Lake Powell, March 1979.

Species	Padre Bay	San Juan	Rincon	Good Hope Bay	Total	Percent of Catch
Largemouth bass	18	110	30	54	212	28.9
Walleye	109	6	142	120	377	51.4
Black crappie	0	15	8	1	24	3.3
Bluegill	0	3	0	1	4	0.5
Green sunfish	0	3	6	3	12	1.6
Channel catfish	15	1	22	6	44	6.0
Carp	20	1	10	6	37	5.0
Flannelmouth sucker	1	3	1	0	5	0.7
Rainbow trout	3	1	0	1	5	0.7
Striped bass	9	0	1	0	10	1.4
Yellow bullhead	0	0	0	3	3	0.4
All species	175	143	220	195	733	

Table 8. Catch rate (fish/net-day) of fish caught in gill nets, Lake Powell, March 1979.

Species	Padre Bay	San Juan	Rincon	Good Hope Bay	Total <sup>a</sup>	Percent of Catch
Largemouth bass	0.6	3.7	1.0	2.1	1.8	28.9
Walleye	3.6	0.2	4.7	4.6	3.3	51.4
Black crappie *	0.0	0.5	0.3	t <sup>b</sup>	0.2	3.3
Bluegill	0.0	0.1	0.0	t	t	0.5
Green sunfish	0.0	0.1	0.2	0.1	0.1	1.6
Channel catfish	0.5	t	0.7	0.2	0.4	6.0
Carp	0.7	t	0.3	0.2	0.3	5.0
Flannelmouth sucker	t	0.1	t	0.0	t	0.7
Rainbow trout	0.1	t	0.0	t	t	0.7
Striped bass	0.3	0.0	t	0.0	t	1.4
Yellow bullhead	0.0	0.0	0.0	0.1	t	0.4
All species	5.8	4.8	7.3	7.5	6.3	

<sup>a</sup>Total fish divided by total nets.

<sup>b</sup>Less than 0.1 fish/net-day.



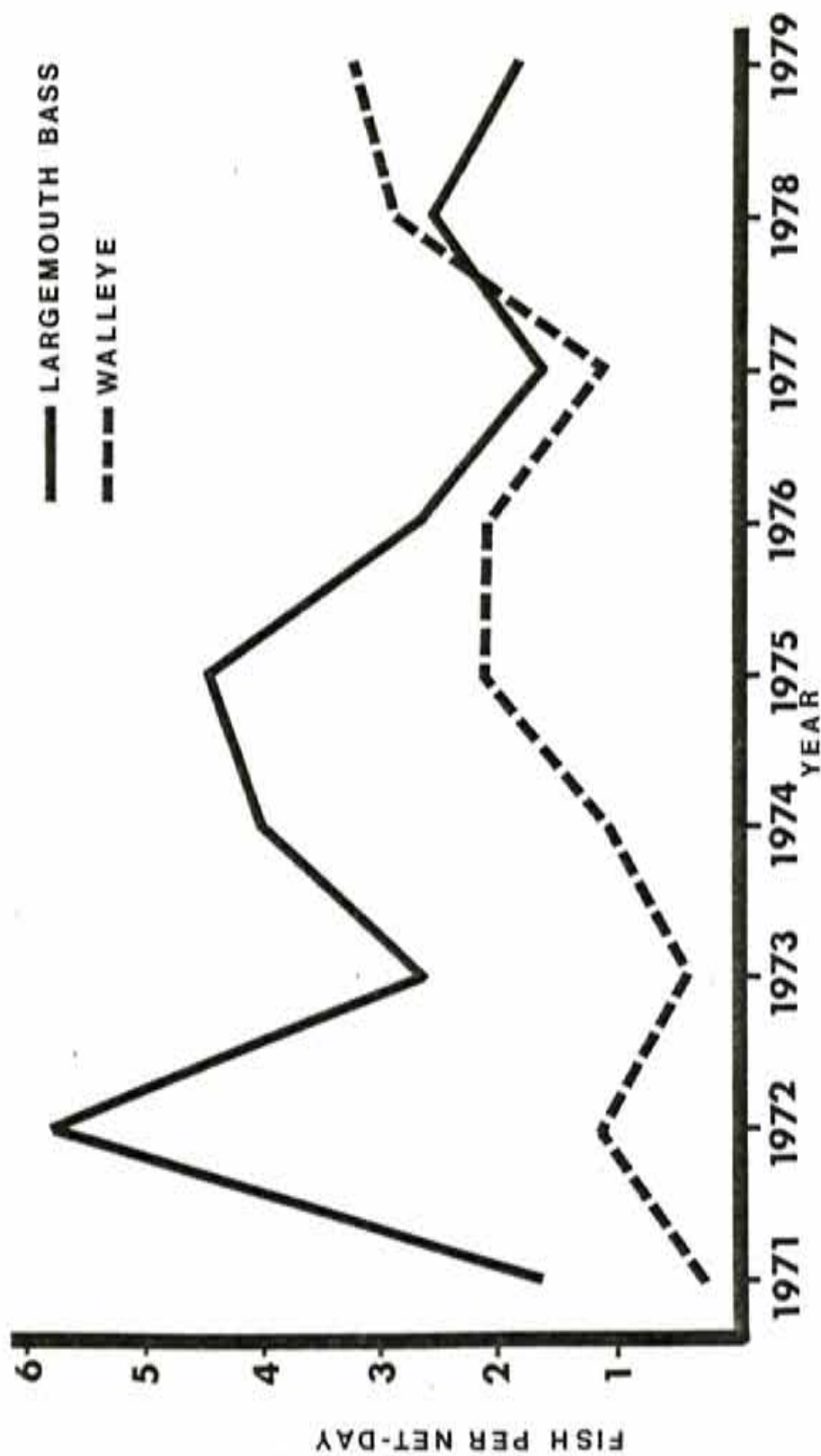


Figure 10. Catch rates (fish/net-day) of largemouth bass and walleye from annual netting, 1971-79, Lake Powell.

(Figure 10). The Rincon accounted for most of the increase in the overall catch rate of walleye in 1979. Numbers of walleye caught there were up over 50%. There was a significant correlation (5% level) between the catch rate of walleye for the nine years of annual netting and the age of the reservoir according to Spearman's rank correlation coefficient (Snedecor and Cochran 1971). The catch rates for largemouth bass did not show a correlation with reservoir age as determined by the same test. According to the netting indices, however, densities of bass have decreased annually since 1975, except for 1978. It is possible that the number of largemouth bass has been affected by the expanding walleye population. Walleyes are competitors of largemouth bass (Niemuth et al. 1962) as well as predators on small bass. Several stomach samples taken from walleye in 1979 contained remains of small largemouth bass. The adverse effects of an expanding walleye population on sympatric species would tend to be accentuated in years when the usual forage base (threadfin shad) was low, as in 1979.

Black crappie, carp and channel catfish were also occasionally caught and together comprised 14.3% of the total gill-net catch. These species have shown no apparent changes in density over the past five years (Table 9). Striped bass were first collected during the annual net sampling in 1977, and have made up about 5% of the catch at Padre Bay in 1978 and 1979. The expanding range of striped bass was also documented in 1979. For the first time since their introduction, a striped bass was collected during the annual netting at an area outside

Table 9. Catch rate by species and year, annual gill netting, Lake Powell, 1971-79.

Species	Catch Rate								
	1971	1972	1973	1974	1975	1976	1977	1978	1979
Largemouth bass	1.65	5.82	2.71	4.01	4.49	2.72	1.85	2.61	1.83
Walleye	0.29	1.12	0.41	1.09	2.15	2.11	1.17	2.84	3.25
Black crappie	0.12	0.67	0.12	0.27	0.36	0.27	0.26	0.33	0.21
Bluegill	0.12	0.52	0.06	0.05	0.04	0.10	0.09	0.04	0.03
Green sunfish	0.10	0.16	0.09	0.13	0.06	0.04	0.09	0.10	0.10
Channel catfish	0.12	0.43	0.21	0.14	0.25	0.16	0.20	0.29	0.38
Carp	1.14	0.79	0.32	0.34	0.36	0.38	0.44	0.34	0.32
Flannelmouth sucker	0.18	0.28	0.21	0.17	0.08	0.08	0.03	0.03	0.04
Rainbow trout	0.24	0.31	0.10	0.08	0.19	0.25	0.26	0.11	0.04
Brown trout	0.02	0.00	0.01	0.03	0.04	0.04	0.02	0.01	0.00
Striped bass	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.09
Yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.03
All species	3.98	10.10	4.24	6.31	8.02	6.15	4.44	6.82	6.32

Bay is the station nearest the stocking point for striped bass). In March 1979, a 510 mm TL striped bass was collected at Rincon.

A total of 3,305 fish was collected during 15 hours of electrofishing for an overall catch rate of 400 fish/hr.

Young-of-the-year black crappie were caught most frequently at the transects, making up 42.9% of the total. Green sunfish and largemouth bass each made up over 17% of the total catch. This is the only other species collected in significant numbers other than the total. Limited numbers of channel catfish, red drum, and older largemouth bass and one young-of-the-year black crappie were also caught during sampling at the five transects. The catch rate of young-of-the-year largemouth bass in 1979 was the lowest recorded for the previous years at Rincon, Hall's Canyon (Figure 11). The electrofishing indices for 1979 were a weaker year class compared to that of 1978 at the five transects--Crappie Cove and Stanton Creek. Electrofishing for young-of-the-year black crappie demonstrated a very strong year class in 1979. The mean catch rates at the five transects were higher than those recorded in 1978. The strong year class of black crappie was also suggested by the midwater trawl catches of threadfin shad. Substantial numbers of young-of-the-year black crappie were found in early summer trawl samples. In addition, a few small crappie were collected while trawling.

Table 10. Mean catch rate (fish/hr) of fish caught by electrofishing, Lake Powell, August-September 1979.

Species	Rincon	Hall's Creek Bay	Stanton Creek	Crappie Cove	Knowles Canyon	% of Total Catch
Young-of-the-year largemouth bass	72	84	44	72	87	17.7
Age I and older largemouth bass	2	1	4	6	1	0.5
Young-of-the-year black crappie	217	238	166	86	141	42.9
Green sunfish	65	85	33	32	145	17.5
Bluegill	44	19	31	48	165	15.1
Red shiner	--	38	25	1	5	4.1
Channel catfish	6	12	13	10	4	2.2
All species	406 <sup>a</sup>	477	316	255	548	

<sup>a</sup>Total fish divided by total hr of electrofishing.

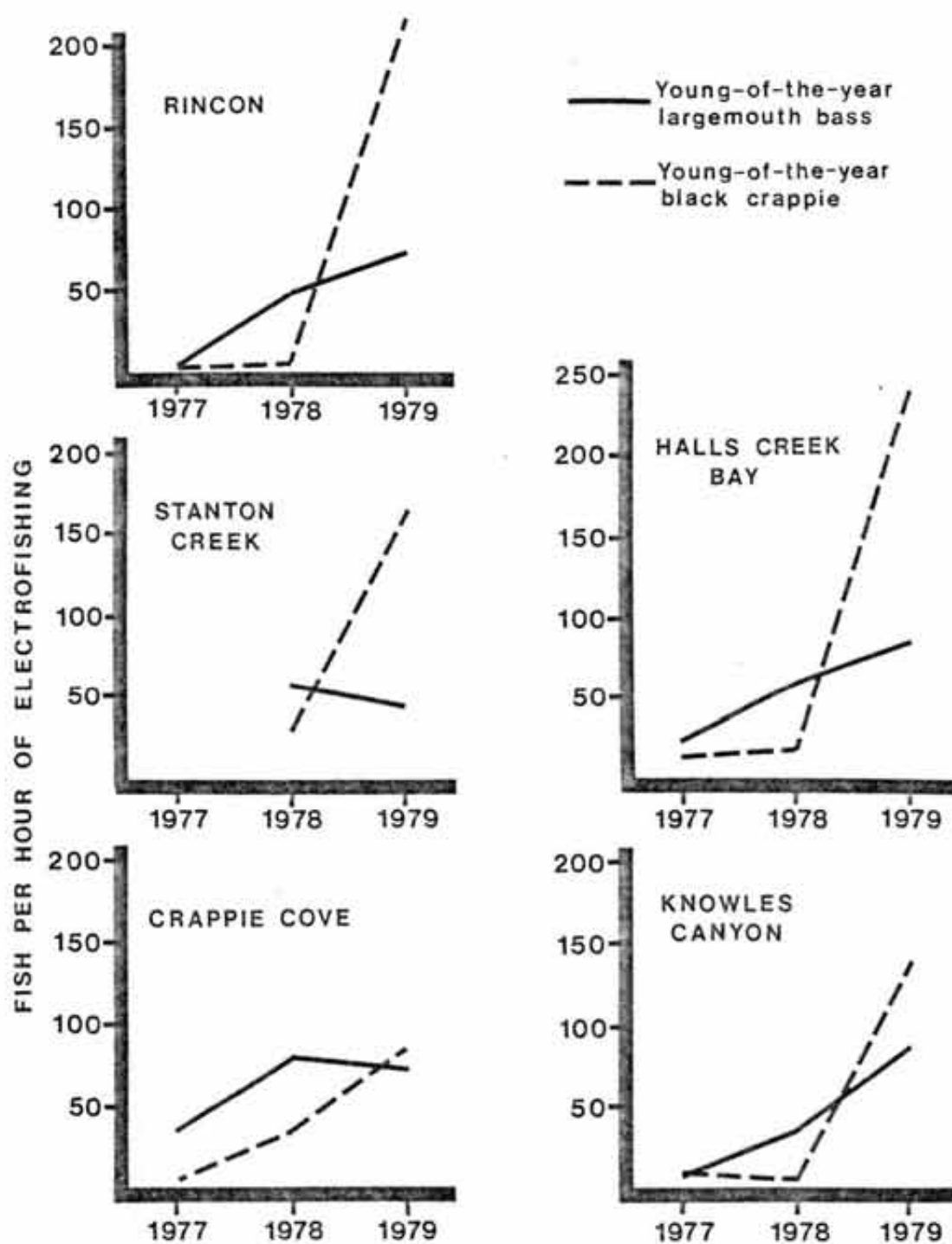


Figure 11. Mean number of young-of-the-year largemouth bass and black crappie collected/hr of electrofishing during August-September 1977-79, Lake Powell.



Year-class strength of largemouth bass and black crappie is governed by a number of factors, including water level fluctuations during spawning season (von Geldern 1971), wind conditions (Miller and Kramer 1971), and competition and predation by other fishes (Kramer and Smith 1960). Water levels at Lake Powell usually are rising during the spring spawning season. In 1979, water levels reached a new record high level. Such conditions are usually associated with strong year classes of centrarchids. The low density of threadfin shad in 1979 may also have been a factor in the production of a strong year class of crappie. von Geldern (1971) described an inverse relationship between the abundance of adult threadfin shad and numbers of fingerling largemouth bass in Lake Nacimiento, California. He concluded that an abundance of adult threadfin shad was detrimental to spawning success or fingerling survival of bass. Black crappie may be similarly affected. Young-of-the-year centrarchids and adult threadfin shad were often found together in littoral zones during electrofishing and may have been competing for food.

Factors other than those affecting relative abundance may influence catch rates obtained by electrofishing and gill netting. Some of these include fish behavior, shape and structure of fish, weather conditions during sampling and operator skill and experience. The modification of the electrode system on the electrofishing boat may have also influenced sampling efficiency and catch rate. In tests of the new system, however, the modifications did not visibly alter the effective range of the electroshocker. The dramatic increase in catch rates of only certain species sampled also suggests a real change in population



densities of those species rather than a change in overall effectiveness of the sampling gear.

#### Recommendations

The annual netting has traditionally been conducted during the month of March, coinciding with the spawning season of walleye. Walleye utilize the rock and rubble habitat found at all netting stations for spawning. Consequently, their vulnerability to gill netting may change significantly depending upon the timing of sampling and the initiation of spawning activity for a given year. It is recommended that limited netting be conducted during the fall to determine if any bias is resulting from the timing of the annual gill-net sampling.

It is also recommended that the condition of fish at the time of annual netting be monitored. An index similar to the visceral fat method used in the Utah Division of Wildlife autopsy classification should provide a means of quantifying fish condition.

When Lake Powell fills completely in 1980, very little suitable habitat for young-of-the-year centrarchids will remain in Crappie Cove. Since two other electrofishing transects are currently sampled in the Bullfrog-Hall's Creek area, it is recommended that the Crappie Cove transect be deleted from the electrofishing sampling schedule. The addition of a transect at North Wash near Hite would provide information over a larger geographic area of the lake.

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## STRIPED BASS CULTURE

## JOB IV

Background

The establishment of a fishable population of striped bass was a primary program objective of the Lake Powell project. The striped bass used in accomplishing this goal were the result of experimental pond culturing of fry donated by other state agencies.

The Lake Powell culture program began in 1973, when six dirt ponds covering 3.2 ha were constructed near Glen Canyon City, Utah. The ponds were part of a land rehabilitation project in an area previously used for gravel mining operations. Studies were undertaken immediately upon completion of the ponds to determine the effect of fertilization upon pond productivity. The plankton responses among ponds were varied, but these studies laid the groundwork for future research (Gloss and May 1974).

The first striped bass fry were cultured at the Glen Canyon facility in 1974, and an annual fingerling crop has been produced through 1979. Fingerling production generally increased each year as culture procedures were refined.

Striped bass culture was conducted with Dingell-Johnson funding support from 1973-1978. Federal Aid funding was not provided for any aspects of striped bass culture in 1979. This report provides a review of striped bass culture activities for the entire 1974-79 period, emphasizing the 1979 season, without regard to funding sources.

## Methods

Preseason treatment. Ponds were kept dry from August to March each year. Drying the ponds prevented some aquatic weed growth and the proliferation of aquatic insects. In 1978 and 1979, bentonite was applied during the off-season to seal the ponds. Bentonite was spread in an even layer, 10 cm thick, over the dry pond bottom. All weeds, old hay and dried aquatic plants were burned before each culture season. Maintenance of drain and inlet piping and gates was performed before filling began.

Fertilization. Ponds were fertilized at various rates with alfalfa hay. Best success was obtained by using 3,358-3,925 kg of hay/surface ha. In 1979, 3,925 kg were used compared to 3,358 kg in 1978, with approximately similar results. Hay was spread over the dry pond bottom prior to filling. After filling, floating hay was forced under the water with pitchforks and broken up to cause it to sink as soon as possible and thereby shorten the oxygen depletion period.

Filling. The ponds were filled from a 61 m deep well pumping groundwater from beneath Wahweap Creek. The water is ideally suited for striped bass culture. It flows at a constant 67 F and is very hard containing 280 mg/l carbonate alkalinity, 339 mg/l bicarbonate alkalinity, and 497 mg/l total hardness.

The pump was turned on 20-24 days prior to expected fry arrival. The hay was placed in the deepest part of the pond so that it would be wet as soon as filling began. It required approximately 17 days of continued pumping to fill the six ponds. Once full, water levels were maintained by pumping water 12 hr/day.



Oxygen and plankton development. After filling, ponds were monitored regularly for oxygen and plankton development. Oxygen samples were taken early each morning until saturation was reached. Dissolved oxygen content was determined using the Winkler titration method. Plankton samples were taken every fourth day to identify types and sizes of plankton. Zooplankton estimates were determined by filtering 9 liters of pond water through a Wisconsin plankton net (#20 mesh bolting). All samples were concentrated to facilitate enumeration in a Sedgewick-Rafter counting cell. Standing crop estimates were expressed as number of individuals/l.

Supplemental fertilization. Supplemental fertilization with inorganic fertilizer (20-20-20) was used in conjunction with alfalfa hay when ponds were slow to develop an adequate plankton bloom or when blooms began to decrease.

Stocking of fry. Fry have been donated by various state agencies throughout the study period. Virginia, and North and South Carolina have donated fry, but these are available before climatic conditions are optimal in southern Utah. Most of the fry used recently have been donated by California because fry are available there in mid-May when daily temperatures have moderated and unstable spring weather conditions have passed.

Fry were transported in water filled plastic bags that were charged with oxygen and then placed in styrofoam boxes. The fry were flown to Page, Arizona, and transported from the airport to the culture facility by truck. The fry were stocked at a rate of 247,000/ha. They were

placed in the ponds after sunset to prevent exposure to direct light. They were temporarily housed in tempering baskets, which were approximately  $1 \text{ m}^3$  in volume and constructed from saran cloth (0.5 mm mesh) stretched over a wood frame. The baskets were protected from wave action by  $2.5 \times 15.2$  cm boards that were fixed in position at the water surface and completely surrounded the basket, creating a buffer zone between boards and basket. The baskets were covered with burlap to prevent surface entry of direct light and aquatic insects. The baskets were fixed at least 30.5 cm above the bottom which protected the fry from silt and low quality water near the bottom. Recommended maximum density in the basket was 100,000 fry/ $\text{m}^3$  (Bonn et al. 1976). Multiple baskets were used in ponds requiring more than 100,000 fry for adequate stocking. The fry could be readily observed in the tempering baskets and subjective estimates of relative survival during pond acclimation were determined.

The fry were released from the baskets at six days of age after they had developed fair swimming ability and mouth parts were sufficiently developed for feeding. The baskets were turned on the side and fry allowed to swim free.

The best method for assessing fry survival following the release was to use a bright flashlight at night. A stationary beam directed into the water attracted fry into the lighted area within approximately five minutes. If none were seen, it was not considered conclusive evidence that fry did not survive; however, it did indicate that survival was poor and fingerling production would be low.



Insect control. Diesel fuel was applied to the ponds at a rate of 46.8 l/ha for control of aquatic insects. It was necessary that the treatment be applied during calm weather periods to be effective since a film of oil must cover the entire pond for an extended period (at least 1 hr) to effectively control aquatic insects. Oil treatments were performed one day before expected fry arrival, one day before release from baskets, anytime insects were observed to be increasing, and shortly before harvest. An effective control for gill breathing Odonata larvae and tadpoles was not found.

Vegetation control. Aquatic weed control was attempted annually. Established weed growth (*Chara* spp.) was eliminated by chemical treatment with Diuron 80 at a rate of .67 kg/ha for three consecutive days. Herbicide treatment of established weeds caused oxygen lags as the weeds died and decomposed. Weeds should be treated as early as possible to lessen the severity of the oxygen loss when fish are in the ponds.

In 1978, ponds were darkened by shading with an application of potassium permanganate at 3 ppm concentrations. The chemical in granular form was disseminated by towing burlap bags filled with the chemical through the pond. Potassium permanganate treatment caused a slight disturbance of plankton growth, but plankton numbers returned to previous levels within three days.

In 1979, pond bottoms in selected seining areas were lined with plastic sheets to prevent light from reaching the bottom and thereby eliminate weed growth. The plastic was placed in position before the pond was flooded and care was taken to avoid trapping air under the

plastic when the pond was filled. The plastic had a tendency to float if any air was trapped. Fish tended to congregate over the weed free areas and the harvest was aided by having clear seining areas.

Weeds that grew large and dense enough to interfere with harvesting fish were mechanically removed. The most expedient mechanical method was to drag chains across the bottom and up on shore where the weeds were deposited.

Fry food habits. Stomach contents were taken from striped bass that were 10-32 days old. Fish were collected with small dip nets from sample baskets left in each pond for that purpose and directly from the pond when large concentrations of fish made this possible. Stomachs were observed under a dissecting microscope (3X) and total contents identified and enumerated. A comparison was made between relative abundance of plankton in the pond and plankton found in the stomachs to show type and size of plankton preferred by striped bass fry.

Supplemental feeding. If the preferred zooplankton bloom utilized by the striped bass was lost or overcropped, an artificial feed, Silver Cup Salmon Starter, was offered at 5.6 kg/ha/day. Fish could be trained to come to the feed, which was broadcast about the pond edges, within three to five days. A mixture of ground beef liver and artificial feed was used initially to train the fish, but results were no different than when artificial feed was used alone. The feeding rate was increased to 11.2 kg/ha/day when fish became dependant on the food.

Harvest. The fish were generally harvested at 50-60 days of age. Small seine samples were taken immediately prior to harvest to determine

number of fish/kg. The ponds were then partially drained to concentrate fish which were harvested with beach seines (0.64/cm mesh). Artificially fed fish could be concentrated by broadcasting feed in the seining area. The fish were taken from the seine and placed in previously weighed buckets of water. The buckets were then reweighed to determine weight of fish before the fish were placed in a fish-distribution truck. An estimate of number harvested was then obtained, using total fish weight and number of fish/kg estimates.

A 0.3% salt solution was added to the water in the fish truck to aid in osmoregulation and stress recovery, which greatly reduced hauling and handling losses. Oxygen levels were maintained by bubbling compressed oxygen through air stones mounted in the tank. Bonn et al. (1976) recommend hauling densities for 5 cm fingerling of 30 g/l for water temperatures below 21 C. Lower densities were recommended for temperatures higher than 21 C.

Fish were released from the truck through a quick release gate. Handling striped bass with a dip net twice in a 24-hr period results in unnecessary mortality (Bonn et al. 1976); consequently, handling fingerling with nets was avoided whenever possible.

### Results and Discussion

Fingerling production generally increased each year as culture techniques were refined (Table 11). In 1979, four of the six ponds produced fry crops. Of the 1,225,000 fry stocked, 225,550 (18%) survived to harvest (Table 12). The other two ponds failed due to oxygen depletions resulting from algal bloom die-offs during the week following introduction. Good production was attributed to timing fry

Table 11. Fingerling survival and total production of culture ponds, 1974-79.

Year	Production/ha	Fertilization kg of Hay/ha	Percent Survival	Total number Produced
1974	23,509	2,240-5,040	4	49,885
1975	30,689	2,240-5,040	5.5	94,878
1976	17,084	4,200	4	55,057
1977	43,509	2,800	14	138,653
1978	78,388	3,360	21	254,290
1979	67,795	3,920	18	222,550
Total				815,313

Table 12. Production/ha during 1979 culture season.

Pond	Hectares	Stocked	Produced	Survival	Production/ha
1	0.19	75,000	3,919	5%	21,037
2	0.17	75,000	0	0	0
3	0.38	180,000	32,371	18%	84,136
4	0.30	110,000	188	0	635
5	1.05	335,000	103,437	31	98,230
6	1.15	450,000	82,635	18	71,844
Total	3.28	1,225,000	225,550	18	67,795

introductions to coincide with the early developmental stages of the naturally occurring zooplankton bloom. Successful ponds were characterized by fry introductions which occurred before the nauplii copepod count had reached 100/l (Figure 12). Production was inhibited if the nauplii count exceeded this figure prior to introduction. The 100/l figure marks a point where the rotifer population is declining, nauplii copepods are increasing in body size, and aquatic insects have attained a large enough size to start preying on the fish. The time has passed when the fry can be the single top level predator in the small plankton food chain. If introduced into this environment, fry must compete with insects and tadpoles for small food organisms and avoid larger organisms which may prey upon the fry.

It is apparent that the role of rotifers in the initial feeding response has been underrated. The literature supports the importance of nauplii copepods in striped bass fry diets, but generally lists rotifers as unimportant although little information is available on food habits during the first week of life (Humphries and Cummings 1973). Our earliest attempts to define food habits show an early reliance on rotifers in those ponds with a strong rotifer bloom (Table 13). In three of the four most productive ponds since the project began, a strong rotifer bloom preceded a strong nauplii copepod bloom and the fry were introduced in the developmental stages of the rotifer bloom.

Most mortality of introduced fry occurred during the first week. Fry must have an ample supply of small plankters available as they absorb the yolk sac and begin feeding. If a feeding pattern was not established at this time, the majority of fish starved. Once on food,



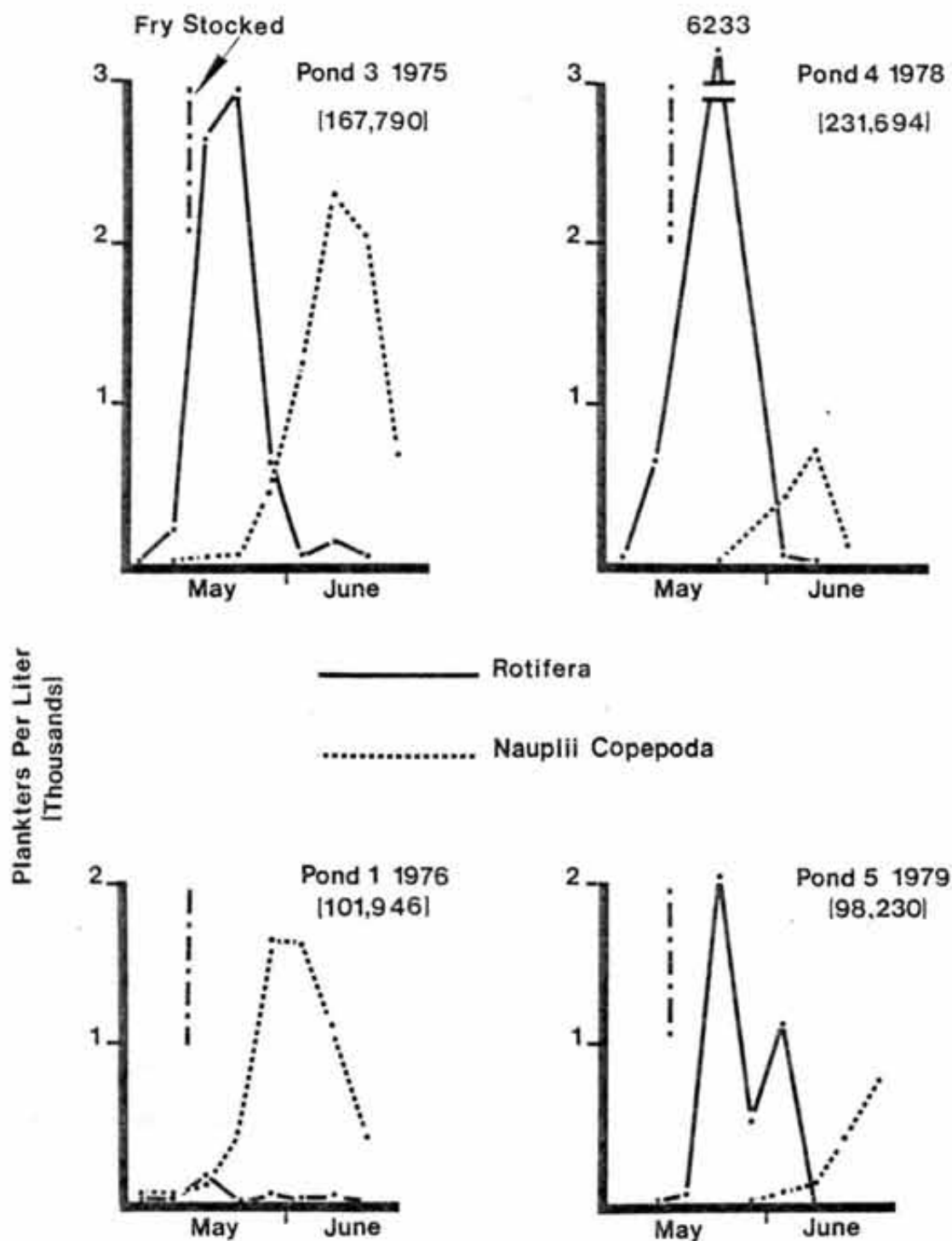


Figure 12. Timing of fry introductions in relation to relative abundance of small plankters in the most productive ponds from culture seasons, 1975-79. Fingerling production/ha is listed in brackets.

Table 13. Food habits of 13-day-old fry during 1978, the most productive culture season.

Pond	Sample Size (n)	Empty Stomachs	Average Total Length	Number of Food Organisms			
				Rotifers	Nauplii Copepods	Adult Copepods	Ostracods
1	3	1	7 mm	1	1	1	--
2	5	0	8	34	1	--	--
3	10	7	6	--	2	--	3
4	5	3	8	6	--	--	--
5	4	3	8	2	--	--	--
<hr/>							
Total	27	14	7.1 mm	43	4	1	3
Percent by number				84%	8%	2%	6%
Percent occurrence in stomachs containing food				69%	31%	8%	15%



the fry grew in direct proportion to the magnitude of the relative standing crop of plankton. After three weeks, fry preferred a diet of adult copepods and adult cladocerans.

In the event the plankton bloom was lost to overcropping or naturally occurring cycles, the striped bass fingerlings would utilize artificial feeds. If feeding was required, the fingerlings learned to come to broadcast feed within three to five days. Learning was probably hastened by mixing feed with ground beef liver for the first day although we have successfully started fish with broadcast feed only.

The control of aquatic weeds was the biggest challenge during the project period. Absence of weeds was essential to a successful harvest. Attempts to inhibit weed growth by shading the ponds with potassium permanganate were not successful. The chemical provided a temporary reduction in visibility but it was not enough to limit light to the aquatic plants. They still grew well in ponds that were treated. Lining portions of the pond bottom with plastic sheets showed good potential. The lined areas were weed-free during the harvest and fish could be congregated in these seining corridors by herding, crowding and/or feeding.

#### Recommendations

A preemergent treatment of herbicide is recommended to retard aquatic weed growth. The chemical should be applied to the dry pond bottom to cause as little interference with plankton and oxygen levels as possible. Herbicides should be used sparingly since their effects may be cumulative and cause a decline in future pond productivity. Long-term effects from annual chemical treatments have not been determined and more research is needed on this subject.

Plastic used to line selected seining areas should be black in color to prevent light penetration. This method of vegetation control deserves further attention.

Ponds should be filled 20-24 days before expected fry arrival and fertilized at a rate of 3,500 kg of hay/surface ha.

Supplying newly hatched brine shrimp to the fry in the tempering baskets would be a means of ensuring availability of plankters in the event the rotifers or nauplii copepods are slow in developing. Brine shrimp introduction should become standard procedure during the period of fry confinement in tempering baskets.

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## EVALUATION OF STRIPED BASS INTRODUCTION

## JOB V

Background

Striped bass have been stocked annually into Lake Powell since 1974. Approximately 80% of the fingerlings were released into Wahweap Bay. Bullfrog Bay was stocked with striped bass fingerlings from 1976-78. Sampling of the striped bass population was designed to supply information on survival, growth and food habits. Data on distribution and development of a sport fishery were largely collected as part of the regular creel census program (Job II). Striped bass have shown excellent growth and high utilization of threadfin shad in their diet.

Methods

Striped bass were generally collected from Lake Powell with gill nets. A few young-of-the-year striped bass were caught with beach seines. Creel census returns and angler reports (Job II) were used in conjunction with netting surveys (Job III) to monitor distribution and movements from the original stocking areas.

Lengths, weights, stomachs and scales were collected from all striped bass. Stomachs and their contents were preserved in 10% formalin for later examination. Stomachs were examined to determine contents, and food items were classified by number, volume and occurrence. Scales were taken from below the lateral line and posterior to the pectoral fin. Impressions of the scales were made on acetate cards with a heated press. They were read and measured with the aid of a microprojector.

## Results and Discussion

All of the 222,550 striped bass fingerlings raised in 1979 were stocked in Wahweap Bay (Table 14). A total of 815,313 striped bass fingerlings have been stocked in Lake Powell since 1974.

The Colorado River above Lake Powell was sampled during May 1979, for the presence of spawning striped bass. Four gill nets were set in Cataract Canyon for two days but no striped bass were collected. No striped bass were reported by anglers at Hite until later in the summer.

Near the end of May 1979, large numbers of adult striped bass were reported at the inflow of the San Juan River where it enters Lake Powell. The local conservation officer reported that anglers caught several striped bass near Copper Canyon where the current from the river became noticeable. Three sampling trips were made to the San Juan in search of young-of-the-year striped bass but none were collected.

On May 29, 1979, striped bass eggs were found near the mouth of Antelope Canyon, 6.4 km from Glen Canyon Dam. Dead eggs were clearly visible for several hundred meters. Most of them were covered with fungus. The eggs were identified using characteristics and photographs presented in Bonn et al. (1976). All of the other fishes in Lake Powell have eggs that sink and/or are adhesive. Several tows with a meter net failed to reveal any live eggs or striped bass fry. Seining was tried prior to stocking striped bass in Wahweap Bay but none were collected. A ripe male striped bass was found dead near the drifting eggs. In June 1979, an adult female striped bass with one spawned out ovary was collected near where the eggs were observed.

Table 14. Striped bass stocking history of Lake Powell.

Year	Wahweap	Number Stocked		Total
		Bullfrog		
1974	49,885	0		49,885
1975	94,878	0		94,878
1976	35,752	19,305		55,057
1977	86,003	52,650		138,653
1978	169,469	84,821		254,290
1979	222,550	0		222,550
Total	658,537	156,776		815,313



In August 1979, beach seining was employed in Wahweap Bay to sample for young-of-the-year striped bass. Seining was very difficult due to record high lake levels. Areas shallow enough to seine were very brushy, and clear sandy bottom areas were nearly nonexistent. An average of 2.5 young-of-the-year striped bass/haul was captured in four seine hauls which was comparable to results obtained from sampling other year classes of recently introduced striped bass (Table 15). This sampling effort should not be considered to accurately indicate magnitude of the year class, but the presence of young-of-the-year striped bass was detected with minimum effort, indicating survival of stocked fish was substantial.

On 12 August 1979, a young-of-the-year striped bass (112 mm TL) was collected while electrofishing in Bullfrog Bay. This was a very significant catch because the 1979 stocking site was 160 km from Bullfrog Bay. Subsequent beach seining effort in Bullfrog Bay produced no other striped bass but further seining effort was employed in other locations. On 10 September 1979, three seine hauls in North Wash (Hite area) produced five young-of-the-year striped bass that averaged 105 mm TL. These fish were 240 km from the 1979 stocking location. September seine hauls in Wahweap Bay produced no fish even though schools of young-of-the-year striped bass were seen in the seining area. A combination of clear water, brushy seining areas and advanced size of fingerlings rendered seining at Wahweap ineffective in September.

Small mesh gill nets were set at Wahweap and Hite to sample young-of-the-year striped bass. Two nets set on two nights in Wahweap Bay captured two of the introduced fingerlings (0.5 fish/net night). Two

Table 15. Average catch/seine haul of young-of-the-year striped bass introduced into Wahweap Bay, 1975-1979.

Year (August)	Number Stocked Wahweap Bay	Total Fish Collected	Total Number of Seine Hauls	Average Catch/haul
1975	94,878	53	18	2.94
1976	35,752	5	12	0.42
1977	86,003	42	7	6.00
1978	169,469	32	7	4.50
1979	222,550	10	4	2.50

nets set on each of four nights in North Wash resulted in six young-of-the-year striped bass (0.75 fish/net night). Average length of the Wahweap fish was 110 mm, while those captured at Hite were 130 mm. It appeared that a significant population of striped bass was naturally reproduced in the Colorado River above Hite in 1979.

The average growth of Lake Powell striped bass collected between 1975 and 1979 is illustrated in Table 16. Growth of young striped bass decreased over the sampling period. The most substantial reduction occurred in 1979, and probably reflected the reduced shad population in the lower reservoir. Even with slower growth rates, Lake Powell striped bass are still growing very well compared to other populations (Table 17). Only striped bass in Keystone Reservoir, Oklahoma (Erickson et al. 1971), and in Lake Havasu and Lake Mead (Edwards 1974) are growing noticeably faster than those in Lake Powell.

Table 16. Back calculated growth in total length (mm) of Lake Powell striped bass from 1975-79.

Sample Year	Age-Class (Sample Size)				
	1	2	3	4	5
1975	268 <sup>a</sup>				
1976	262 (275)	444 (38)			
1977	266 (119)	444 (27)			
1978	261 (396)	442 (209)	565 (74)	676 (13)	
1979	217 (139)	427 (50)	558 (37)	553 (23)	590 (1)
<hr/>					
Gross Mean	253 (939)	440 (324)	564 (111)	663 (41)	690 (1)

<sup>a</sup>Sample size unknown.

Table 17. Comparison of growth rates of striped bass from various studies. All data converted to total length (mm).

Age Group	Present Study Lake Powell (1979 Data)	Lower Colorado River (Edwards 1974)		California (Robinson 1960)		South Carolina (Stevens 1957)	Maryland (Mansueti 1961)		Oregon (Morgan and Gerlach 1950)	Oklahoma (Erickson et al. 1971)
		Male	Female	Male	Female		Male	Female		
I	217	174	190	112	120	218	145	133	--	280
II	427	453	470	266	266	401	318	312	399	473
III	558	609	648	413	416	505	408	415	516	584
IV	653	712	768	535	620	573	500	529	620	676
V	690	790	873	606	641	658	535	595	679	742
VI	--	851	934	666	731	736	636	690	739	--

Threadfin shad are the most important food item for Lake Powell striped bass (Table 18). Striped bass feed almost exclusively on shad during the winter months. Utilization of threadfin shad appeared to decrease in the spring and was the lowest during the summer months, probably due to thermal separation of predator and prey (Schaich 1979; and Waddle 1979). The standing crop of shad at Lake Powell probably declines from late summer until the next year class is produced. During late spring and early summer, some predation by striped bass on young-of-the-year centrarchids occurs. Most of the identified centrarchids were crappie fry eaten before shad began spawning. Crappie fry are pelagic and travel in schools much like shad. In the summer, striped bass feed on shad larvae (<25 mm TL). Striped bass collected by hook and line this time of year contained an average of 160 shad fry and none had empty stomachs, while those collected in gill nets averaged 0.7 shad and 50% had empty stomachs (Hepworth et al. 1977). Metabolic and digestive rates are much faster in warmer water. Small shad digest rapidly during the summer compared to the chitinous exoskeleton of crayfish, causing underestimation of the role of threadfin in the diet, especially during summer in gill-net samples. Most unidentified fish found in striped bass stomachs were probably shad but because of their advanced state of digestion, identification was impossible.

Young-of-the-year striped bass feed heavily on aquatic diptera until they reach 100-110 mm TL. Generally, early in September, they switched to shad and their growth rate accelerated. By the end of October, they were 200-225 mm. An abundance of young-of-the-year shad was critical for rapid growth of young striped bass. A comparison of the first-year growth of the 1977 and 1978 year classes supports this

Table 18. Food habits, by season, of striped bass collected in Lake Powell from 1975-79.

Food Items	December-February 1975-1979 (n <sup>a</sup> = 76)			March-May 1975-1979 (n = 184)			June-August 1975-1979 (n = 237)			September-November 1975-1979 (n = 267)		
	# by No.	# by Vol.	% Occ.	# by No.	# by Vol.	% Occ.	# by No.	# by Vol.	% Occ.	# by No.	# by Vol.	% Occ.
Crayfish	0.6	5	3	2	2	9.3	4	25	20	2.2	11.2	4
Fish												
Threadfin shad	98.5	94.5	87	88	94	79.6	43	71	40	73.3	86.3	73
Centrarchidae	0	0	0	0	0	0	2	1.5	3	0.1	0.5	1
Unidentified	0.9	0.5	10	5	2	10.2	1	1	6	4.1	2	13
Lepidoptera (larvae)	0	0	0	5	2	0.9	0	0	0	0	0	0
Aquatic diptera	0	0	0	0	0	0	50	1.5	23	20.3	t	9
Odonata	0	0	0	0	0	0	t <sup>b</sup>	t	t	0	0	0
Zooplankton	0	0	0	0	0	0	c	c	14	0	0	0
	Empty = 15 (20%)			Empty = 76 (41%)			Empty = 78 (33%)			Empty = 59 (22%)		

<sup>a</sup> The total number of stomachs collected.

<sup>b</sup> Less than 0.1%.

<sup>c</sup> Data incomplete.



conclusion. In 1977 and 1978, shad were abundant; but during the winter of 1978-79, most of the shad population was lost in the southern third of the lake. Shad production was very low in the Wahweap area in 1979 (Job I). The 1977 year class of striped bass increased 173 mm between October 1977 and October 1978. Striped bass stocked at Wahweap in 1978 grew only 69 mm between October 1978 and October 1979. The growth rate had dropped approximately 100 mm because of the reduced shad population. With 1979's very low shad production, growth should be reduced for all year classes in the southern end of the lake. There should be an adequate number of shad at Hite to allow the naturally produced striped bass to grow at rates similar to those introduced into Wahweap between 1974 and 1977.

#### Recommendations

Intensively study the extent and magnitude of striped bass natural reproduction to determine if numbers of naturally reproduced fish will be high enough to sustain the sport fishery and thereby eliminate the need for stocking. If natural recruitment is of sufficient magnitude, consideration should be given to increasing the creel limit.

Determine whether striped bass spawn exclusively in the tributaries or if some reproduction occurs within the reservoir proper, as some current thought suggests.

Continue to monitor the food habits, growth, relative abundance and distribution of striped bass to document any impact the expanding population may have on the reservoir's other game and forage fish populations.

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