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Lake Powell Fisheries Investigations



Five-Year Completion and 1984 (Segment 13) Annual Performance Report

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

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LAKE POWELL FISHERIES INVESTIGATIONS

Completion Report
January 1980 - December 1984

Annual Performance Report
January 1984 - December 1984

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LAKE POWELL FISHERIES INVESTIGATIONS

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. Lake Powell investigations since 1971 have been funded by Federal Aid to Fish and Wildlife Restoration, Project F-28-R, and by the Utah Division of Wildlife Resources.

New studies undertaken since 1971 include game fish food habits, benthic studies, plankton studies, threadfin shad population dynamics and predator impact, an annual netting program to determine trends in game fish populations, and smallmouth bass culture and stocking. The study of fishing pressure and success has been ongoing since 1963, while the study of the physical and chemical nature of Lake Powell was completed in 1974.

Important events that have occurred since the initial introduction of largemouth bass (Micropterus salmonides), black crappie (Pomoxis nigromaculatus) and rainbow trout (Salmo gairdneri), include the introduction of threadfin shad (Dorosoma petenense) in 1968, introduction of striped bass (Morone saxatilis) in 1974, introduction of smallmouth bass (Micropterus dolomieu) in 1982 (Table 1), and the expansion of the walleye (Stizostedion vitreum vitreum) population which developed from stock present in the drainage before impoundment.

The sport fisheries have undergone several changes since impoundment. The initial introductions of largemouth bass and black crappie were quite successful and developed into an excellent fishery that peaked in the early 1970's. As the lake level approached full pool in 1980, however, a decline in spawning and nursery habitat greatly reduced largemouth bass and black crappie recruitment. To help alleviate this situation and provide more diversity, striped bass and smallmouth bass have been introduced (Table 1). Striped bass are presently well established in Lake Powell and are providing an excellent fishery. Smallmouth bass, which were first introduced in good numbers in 1984 (Table 1), appear well suited to Lake Powell's steep, rocky shoreline habitats and will hopefully provide a good fishery for black bass fishermen in the future.

Findings of our research from January 1980 to December 1984 are given in this report along with detailed results of the 1984 sampling year. More detailed accounts of events occurring in any particular year, 1980 to 1984, can be found in Lake Powell annual progress reports for that year (Gustaveson et al. 1981, 1982, 1983 and 1984).

Table 1. Stocking history of Lake Powell, Utah, 1963-1984.

Year	Species	Number	Size	Area	Method
1963	Largemouth bass	924,000	2-3 "	Warm Creek - Aztec	Aerial
	Rainbow trout	3,000,000	2 "	Reservoir Wide	Aerial
	Rainbow trout	800,000	2-4 "	Wahweap Creek	Truck
	Rainbow trout	35,000	4 "	Hall's Crossing	Truck
	Kokanee salmon	600,000	1-2 "	Kane Creek	Truck
1964	Largemouth bass	1,000,000	2-3 "	Warm Creek-Last Chance	Aerial
	Largemouth bass	250,000	2-3 "	Mouth Escalante	Aerial
	Largemouth bass	250,000	2-3 "	Rincon	Aerial
	Largemouth bass	500,000	2-3 "	Bullfrog Creek	Aerial
	Rainbow trout	3,000,000	2-3 "	Dam-Bullfrog Creek	Aerial
	Rainbow trout	325,650	5-8 "	Hite	Truck
	Rainbow trout	365,730	5-8 "	Wahweap Creek	Truck
	Kokanee salmon	35,000	2-3 "	Wahweap Creek	Truck
	Black crappie	350	6 "	Wahweap Creek	Truck
	Black crappie	9,000	3 "	Wahweap Creek	Truck
1965	Rainbow trout	4,383,525	2-3 "	Reservoir Wide	Aerial
	Rainbow trout	40,000	5 "	Wahweap Creek	Truck
	Black crappie	30,000	1 "	Wahweap Creek	Truck
	Black crappie	4,700	4 "	Wahweap Creek	Truck
1966	Rainbow trout	2,140,000	2-3 "	Reservoir Wide	Aerial
1967	Rainbow trout	344,049	4-5 "	Wahweap-Warm Creek	Aerial
	Rainbow trout	103,205	4-5 "	Hall's Crossing-Bullfrog	Barge
	Rainbow trout	102,590	4-5 "	Red Canyon	Barge
1968	Rainbow trout	201,364	3-5 "	Wahweap Creek	Barge
	Threadfin shad	1,500	1-4 "	Wahweap Creek	Truck
1969	Rainbow trout	251,238	5 "	Wahweap Creek	Barge
	Threadfin shad	200,000	Egg-Fry	Wahweap Creek	Spawning mats
1970	-----NO STOCKING-----				
1971	Rainbow trout	281,000	4-5 "	Bullfrog	Barge
	Rainbow trout	527,000	4-5 "	Wahweap Creek	Barge
	Rainbow trout	40,000	4-6 "	Warm Creek	Barge
1972	-----NO STOCKING-----				
1973	Rainbow trout	233,400	5 "	Wahweap Creek	Truck
1974	Striped bass	49,885	2-3 "	Wahweap Creek	Truck
1975	Striped bass	94,878	2-3 "	Wahweap Creek	Truck
1976	Rainbow trout	50,000	3-6 "	Wahweap Creek	Truck
	Striped bass	35,752	2-3 "	Wahweap Creek	Truck
	Striped bass	19,305	2-3 "	Bullfrog	Aerial

-----continued next page

Table 1. Stocking history of Lake Powell, Utah, 1963-1984 (continued).

Year	Species	Number	Size	Area	Method
1977	Rainbow trout	18,600	5 "	Wahweap Creek	Truck
	Striped bass	86,003	2-3 "	Wahweap Creek	Truck
	Striped bass	52,650	2-3 "	Bullfrog	Aerial
1978	Striped bass	169,469	2-3 "	Wahweap Creek	Truck
	Striped bass	84,821	2-3 "	Bullfrog	Aerial-Truck
1979	Striped bass	222,550	2-3 "	Wahweap Creek	Truck
1980	Rainbow trout	13,210	6 "	Wahweap Creek	Truck
1981	-----NO STOCKING-----				
1982	Smallmouth bass	3,100	2-4 "	Warm Creek	Truck
	Smallmouth bass	59	10-15"	Warm Creek	Truck
1983	-----NO STOCKING-----				
1984	Smallmouth bass	26,600	2-4 "	Wahweap-Warm Creek	Truck
	Smallmouth bass	4,000	2-4 "	Stanton Creek	Aerial

THREADFIN SHAD STUDY

JOB I

BACKGROUND

Threadfin shad have been stocked throughout the Southwestern United States 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 percent of the original plant were young-of-the-year (y-o-y). Sampling in the winter of 1968-69 revealed the shad had spawned their first summer in Lake Powell. Heidinger and Imboden (1974) found that y-o-y 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 found reservoir-wide by summer of 1970 (Gloss et al. 1971).

Threadfin shad tend to spawn in shallow, turbid water along shorelines and in the backs of canyons and bays. As y-o-y shad mature, however, they become more pelagic and are not readily sampled with conventional entrapment gear (Van Den Avyle and Fox 1980, Edwards et al. 1977). The major objective of this study was to develop, through ichthyoplankton netting and midwater trawling, a method for assessing annual reproduction and recruitment of y-o-y threadfin shad into the pelagic zones of Lake Powell. The development of a midwater trawling system was completed in 1976 and a standard ichthyoplankton netting system was developed in 1981. Data collected from 1980-84 were used to determine shad population indices, monitor annual reproduction and reflect monthly and annual population fluctuations.

Threadfin shad are presently the predominant food item of all major game species in Lake Powell (Hepworth and Gloss 1976; May et al. 1975; Gustaveson et al. 1980). 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 formed a baseline for comparing the impacts the expanding striped bass population has exerted on threadfin shad abundance (Gustaveson et al. 1980). Data collected from 1980-84 provides information on shad abundance following intense predatory pressure by striped bass.

METHODS

Threadfin shad spawning was monitored with ichthyoplankton net collections, which began when lake temperatures approached 14C in May, and continued until September. Weekly samples were taken in the backs of bays at Wahweap Creek, Warm Creek, Bullfrog Creek and Hall's Creek. Bi-weekly samples were collected at Red, Ticaboo, Moki and Chaol canyons, while monthly monitoring was conducted at Piute Red Wall, Piute Farms Wash and the San Juan River Inflow (Figure 1). A 5.4 m aluminum Jon boat with a 40 hp outboard motor towed a one-meter, 505 micron ichthyoplankton net just below the water's surface. Three tows, two minutes in duration, were taken at each station, sampling an average volume of 102 m^3 of water per tow. While towing the ichthyoplankton net, the boat moved forward at approximately 0.7 m/s and covered a distance of 129 m per sample. Shallow, turbid water sites at the backs of canyons and bays were chosen for sampling because previous findings have demonstrated that shad in Lake Powell tend to spawn in turbid waters (Gustaveson et al. 1982). Sample locations were adjusted periodically to account for fluctuating water levels.

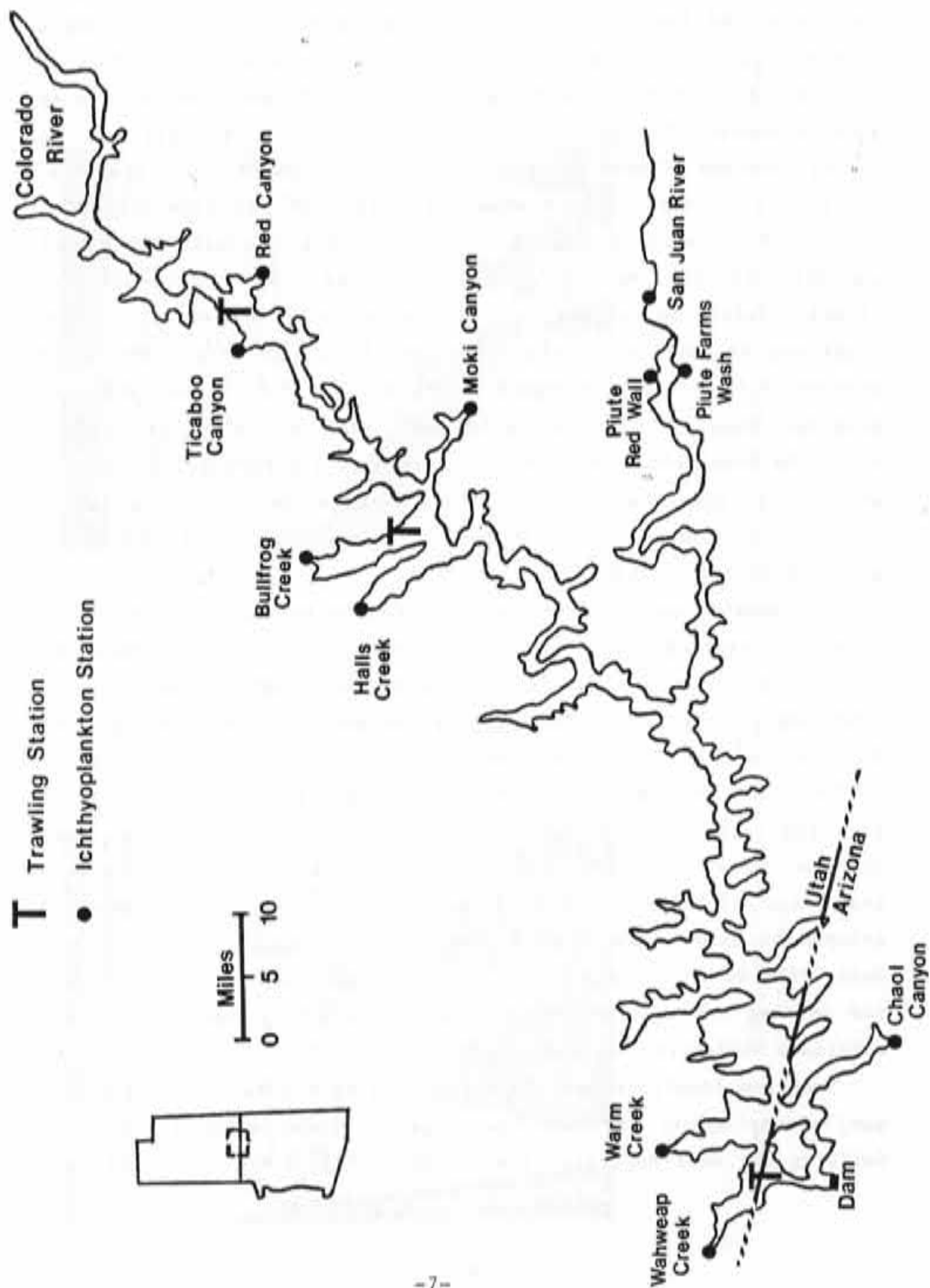


Figure 1. Map of Lake Powell showing trawling and ichthyoplankton netting stations for threadfin shad, 1984.

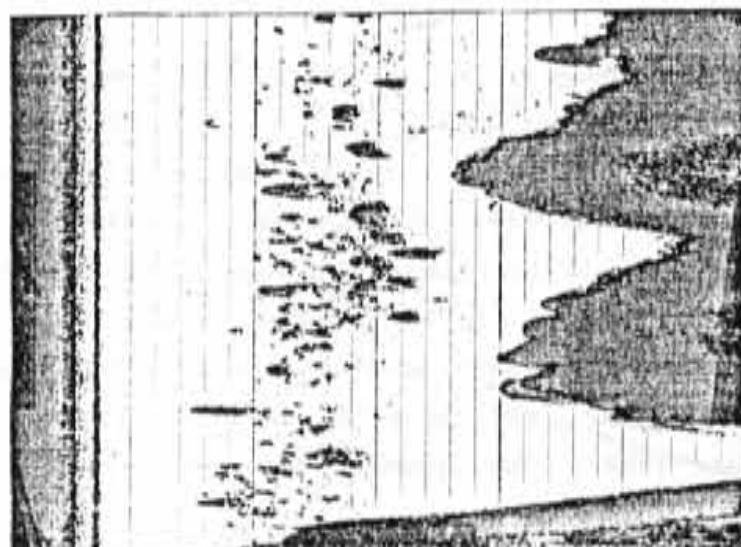
All samples were preserved in the field with 5.0 percent formalin. A solution of biological stain, Phloxine B, was mixed with the preserving formalin to aid in separating larval fish from sample debris. Larval fish were picked from the debris and identified to species. All larval threadfin shad (25 mm TL) were counted and an average number of shad per tow was computed for each station. A monthly average of shad per tow was then calculated for all stations.

An 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 x 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 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/s) while 45.72 m of cable were played out and immediately retrieved. The average volume of water sampled was 8,178.44 m³ 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 instead of grouped in schools as found during the day (Figure 2) (Houser and Dunn 1967; 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.

Trawling locations were selected to sample lake areas near the dam, midway uplake and near the Colorado River inflow at Wahweap, Bullfrog and Good Hope Bay, respectively (Figure 1). Each trawling

DAY

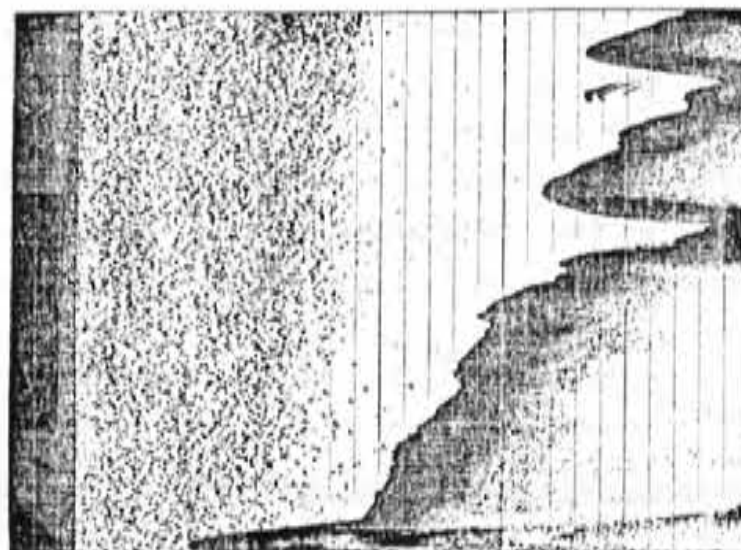


SURFACE

DENSE SCHOOLS
OF SHAD

BOTTOM

NIGHT



SURFACE

UNIFORM LAYER
OF SHAD

BOTTOM

Figure 2. Echograms showing schooling behavior of threadfin shad during the day and random distribution during the night.

location was sampled one night a month from July through September. Wahweap, Bullfrog and Good Hope were sampled on consecutive nights to allow comparison under approximately similar times and conditions. Three standard tows were made each sample night. Floating 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 units, which were also used to generate the echograms of Figure 1, were Lowrance Model 1510 B and C recorders using LPT-101 transducers. The boat was operated on one engine at 800 rpm's during the sonar run. The echograms generated from these runs were used as "back-up" data to the trawl tow information.

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 percent formalin solution. Number of shad, average total length and range, and average weight per catch were determined for each haul.

RESULTS AND DISCUSSION

In Lake Powell, shad generally begin to spawn in early or mid-May at the upper lake locations and by late May at lower lake areas. This is similar to the progressive spawning pattern reported by Netsch et al. (1971) in Beaver Reservoir, Arkansas. Most years, spawning continues at Lake Powell throughout the summer and extends into August at upper lake, and August or September at midlake and lower lake (Figures 3, 4 and 5). Many studies have revealed shad spawning more than once a year, and threadfin shad are known to spawn as y-o-y (Heidinger 1983). Two spawning peaks were observed

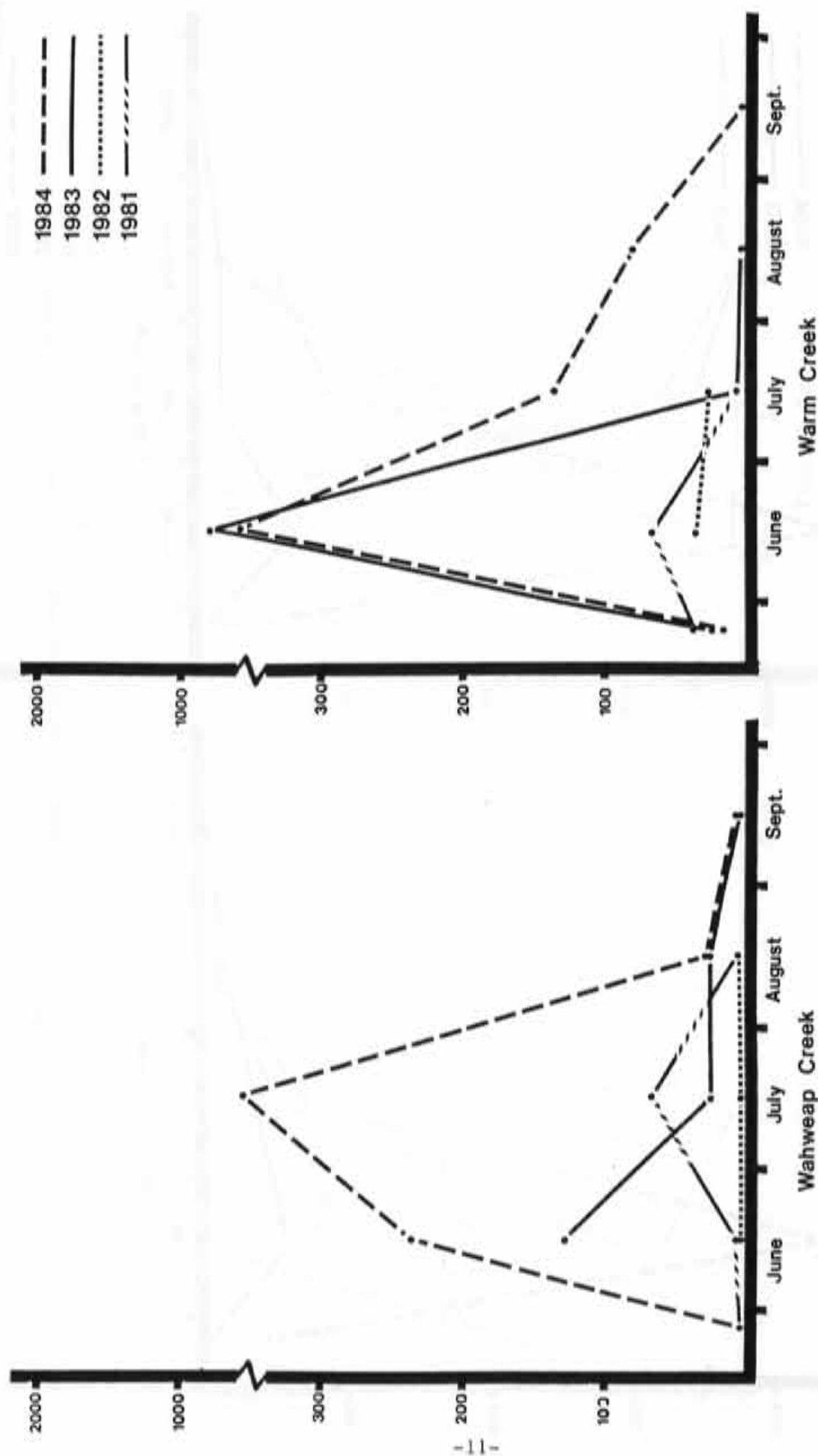


Figure 3. Mean number of larval shad collected per ichthyoplankton tow, lower Lake Powell, 1981-1984.

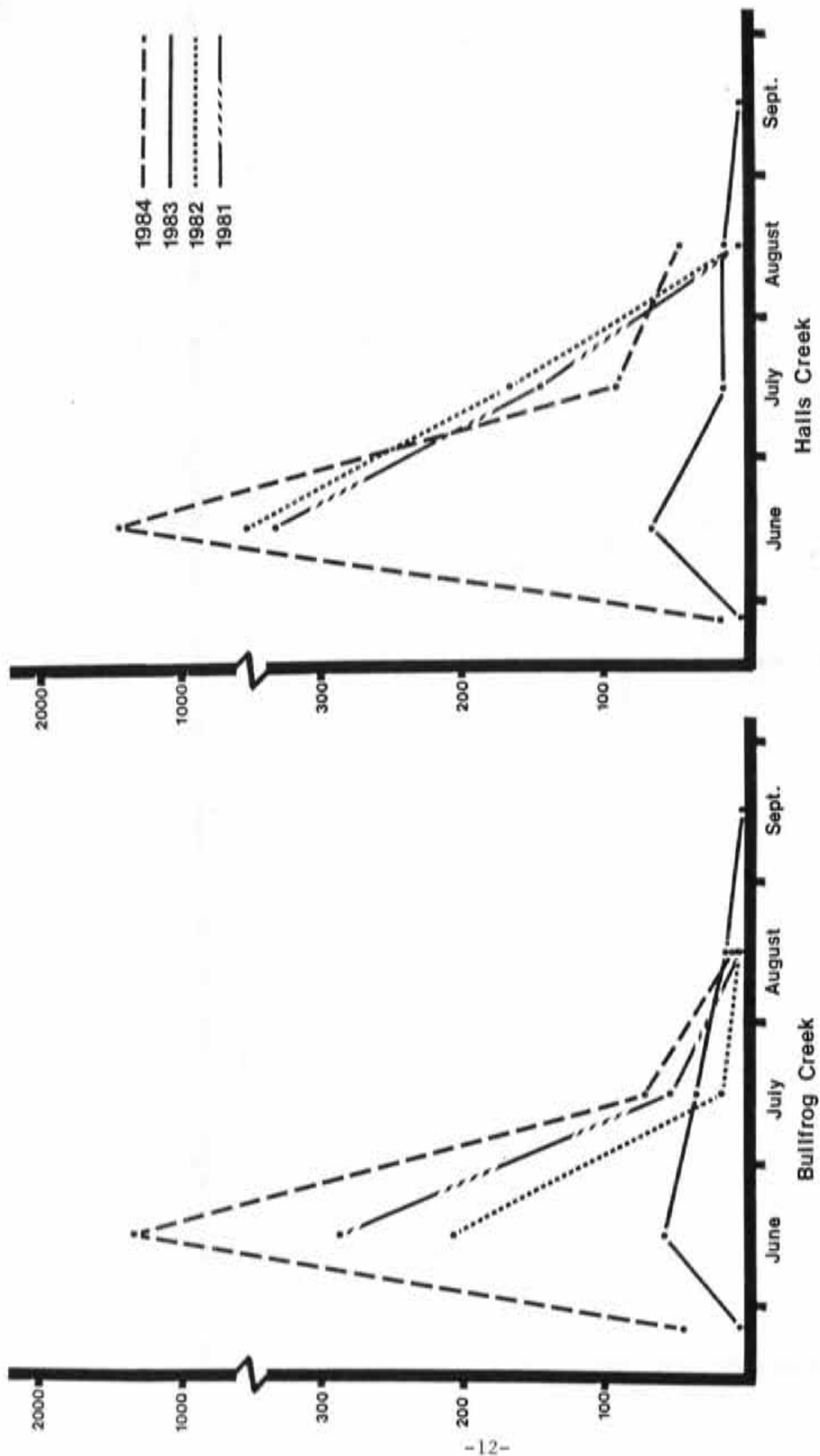


Figure 4. Mean number of larval shad collected per ichthyoplankton tow, mid Lake Powell, 1981-1984.

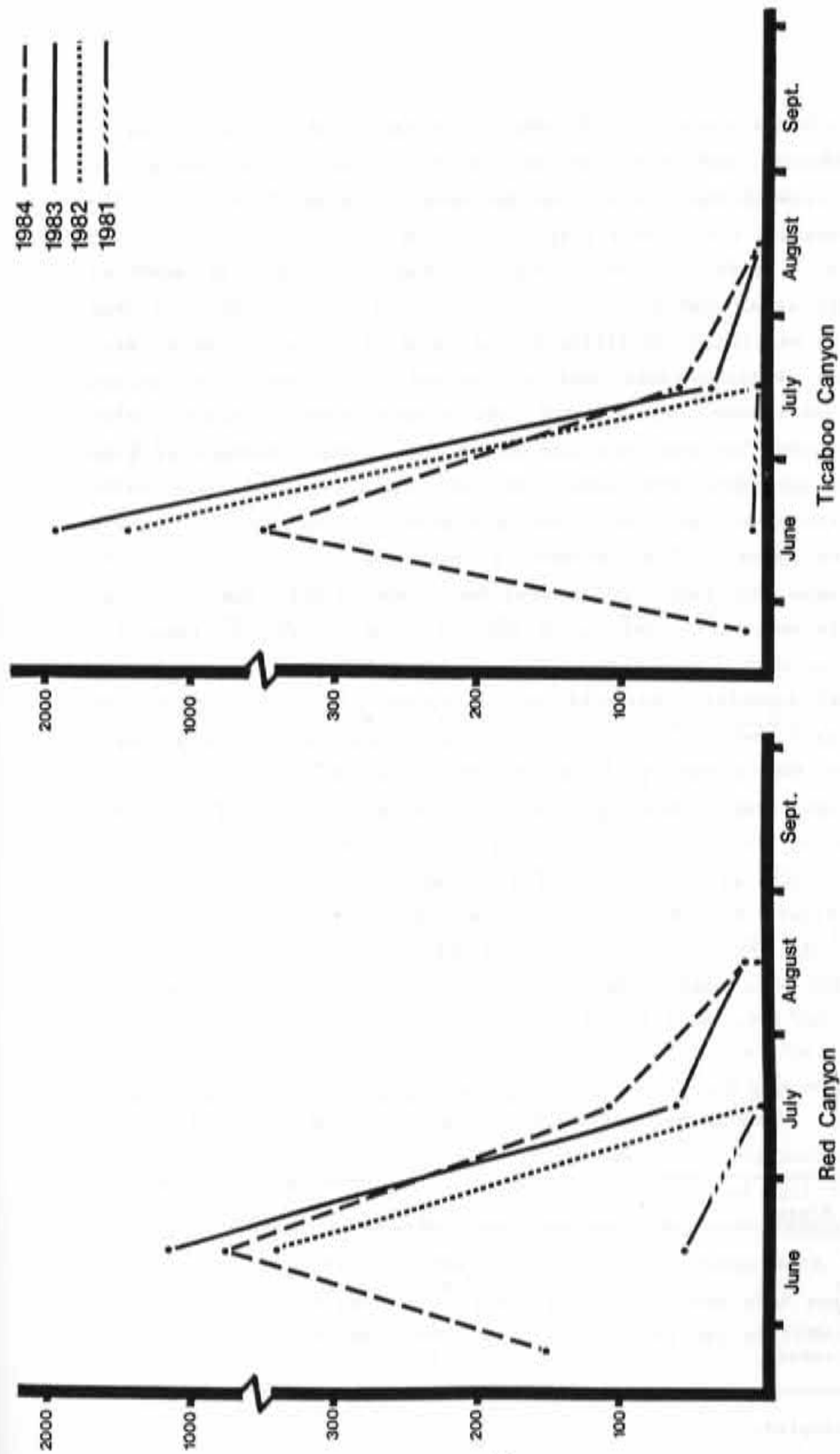


Figure 5. Mean number of larval shad collected per ichthyoplankton tow, upper Lake Powell, 1981-1984.

in California ponds in 1955, and Lake Havasu, California-Arizona in 1956 (Kimsey 1958; Kimsey et al. 1957). Threadfin shad stocked in Hawaii spawned from June through September (Hida and Thompson 1962).

Threadfin shad normally spawn at water temperatures between 14C and 28C. Heidinger (1983) found a thermal cut-off of spawning activity at approximately 30C. He felt that the duration of shad spawning was longer in Illinois study lakes than is typical of more southern states because surface temperature did not often exceed 30C. He found higher shad recruitment where optimum water temperatures for shad spawning occurred for longer periods of time without exceeding the thermal cutoff temperature. Surface water temperatures at Lake Powell seldom exceed 30C for more than a few days in August. The extended spawning season revealed in the ichthyoplankton sampling is, therefore, most likely the result of water temperatures remaining at the preferred temperature range for threadfin shad spawning, without exceeding the 30C cutoff.

Shad spawning, indicated by the number of shad collected per tow, was higher in 1984 than has been recorded since the standard ichthyoplankton netting began in 1981 (Figures 3, 4 and 5). In lower Lake Powell this high point represents two years of high production at Warm Creek, and exceptional production during 1984 at Wahweap, with an average of 415 fish/tow collected in the July samples (Figure 3). Both sample sites exhibited lowest reproduction levels in 1982. Limited ichthyoplankton netting in Chaol Canyon indicated good shad production, but for only one month during 1983 (June) and 1984 (May) in that portion of the lake (Table 2).

Table 2. Mean number of larval threadfin shad collected per ichthyoplankton net tow, Chaol Canyon, Lake Powell, 1983-84.

Sample Month	1984	1983
May	791	a
June	47	335
July	4	1
August	2	1
September	a	1

^a Not sampled.

Spawning success at midlake peaked in June 1984 with record monthly averages of 1314 fish/tow and 1443 fish/tow collected at Bullfrog Creek and Hall's Creek, respectively (Figure 4). Since 1981, the only year that low production has been recorded at midlake was 1983. During 1983, all other lake locations recorded good shad spawning, but highs of only 51 fish/tow and 66 fish/tow, respectively, were recorded for June at Bullfrog Creek and Hall's Creek (Figures 4). Ichthyoplankton netting was also conducted in Moki Canyon during 1984 to assess how well the results from the Bullfrog and Hall's samples reflect midlake trends. Numbers of larval shad collected were very close among the three sites and production trends were essentially the same (Table 3).

Table 3. Mean number of larval threadfin shad collected per ichthyoplankton net tow, mid Lake Powell, 1984.

Sample Month	Bullfrog Creek	Halls Creek	Moki Canyon
May	42	16	4
June	1314	1443	1046
July	70	90	46
August	8	46	0

Shad production in the upper lake was quite high during 1984 and reflected trends observed in 1982 and 1983. June 1984 samples contained 758 fish/tow and 365 fish/tow, respectively, at Red and Ticaboo canyons (Figure 5). The only low production year that has been observed uplake was 1981 when 54 fish/tow and 4 fish/tow were found at Red and Ticaboo canyons, respectively, during June.

Limited netting conducted in the upper end of the San Juan Arm revealed a good shad spawn in May of 1984 at Piute Red Wall (252 fish/tow) and Piute Farms Wash (1200 fish/tow, Table 4). Spawning also appeared good during June of 1983 at Piute Farms with 665 fish/tow being collected at the Piute Red Wall. Some shad spawning did occur in the San Juan River Inflow during May of 1984 (36

fish/tow) but this area was relatively unimportant during the rest of 1984 and all of 1983 (Table 4). Although threadfin shad did not use the San Juan River heavily for spawning in 1983 and 1984, the interface at Piute Farms where the turbid, nutrient rich waters of the San Juan River mix with the lake waters was obviously preferred spawning habitat (Piute Red Wall and Piute Farms Wash samples). Because this area of mixing is quite large at Piute Farms, substantial shad production undoubtedly occurs in this area each year. A similar occurrence probably results in the upper end of Lake Powell where the waters of the Colorado River enter the lake.

Table 4. Mean number of larval threadfin shad collected per ichthyoplankton net tow, San Juan River Arm, Lake Powell, 1982-83.

Sample Month	Piute Red Wall		Piute Farms Wash		San Juan River Flow	
	1984	1983	1984	1983	1984	1983
May	252	a	1200	a	36	a
June	3	665	1	a	1	0
July	0	67	1	a	1	0
August	0	0	0	a	0	0

^a Not sampled.

No primary production studies have been conducted at Lake Powell over the past 5 years. It may be possible, however, to gain some idea of primary production levels through examination of the water records for the lake. This could give some idea of the annual influx of nutrients which could in turn effect primary production and shad productivity. The annual inflows were, in fact, exceptionally high during 1983 and 1984 which coincides with two high production years in most portions of the lake (Table 5). The lowest inflow year (1981) was characterized by low production in upper Lake Powell, but did not appear to exert much effect on shad reproduction in the mid and lower lake areas (Figures 3, 4 and 5). Thus, the

amount of nutrient inflow may have direct impact on shad productivity in the inflow areas of Lake Powell but a somewhat diluted effect in lower lake areas as sediments settle out.

Table 5. Monthly inflow (acre-ft) into Lake Powell, 1980-84.^a

Month	1980	1981	1982	1983	1984
January	661,970	500,269	368,780	701,100	821,040
February	802,208	410,826	472,010	662,210	874,810
March	790,180	389,175	686,150	1,126,190	1,046,460
April	1,146,340	389,916	891,960	1,094,750	1,500,680
May	2,951,360	652,725	2,005,040	2,789,960	4,474,440
June	2,951,038	1,087,500	2,340,720	5,530,560	4,805,880
July	942,365	528,900	1,315,800	3,587,490	2,417,770
August	338,291	331,173	730,140	1,481,710	1,382,150
September	528,231	447,374	815,420	751,090	875,470
October	487,270	605,847	964,150	898,190	1,004,630
November	568,556	456,445	833,380	783,350	925,260
December	548,079	432,247	790,450	809,230	824,870
Total	12,717,888	6,232,396	12,214,000	20,215,830	20,953,460

^a Unpublished data, U.S. Bureau of Reclamation, Reservoir status report, Salt Lake City, Utah.

Midwater trawl catches of y-o-y have varied greatly from year to year, but do show similar trends within years throughout the lake. Since 1980, good numbers of shad were only collected during 1981 and 1984 in trawl samples (Figure 6). Trawl catches in 1981 were 241 fish/tow, 1287 fish/tow and 582 fish/tow at Wahweap, Bullfrog and Good Hope, respectively. This compares with high catches observed in 1984 of 45 fish/tow, 595 fish/tow and 536 fish/tow, respectively. The poorest recruitment years have been 1982 and 1983 when almost no y-o-y shad were collected in trawl tows from all locations (Figure 6).

There is some evidence that the threadfin shad population in Lake Powell may be cyclic. Since 1977, trawl catches have exhibited

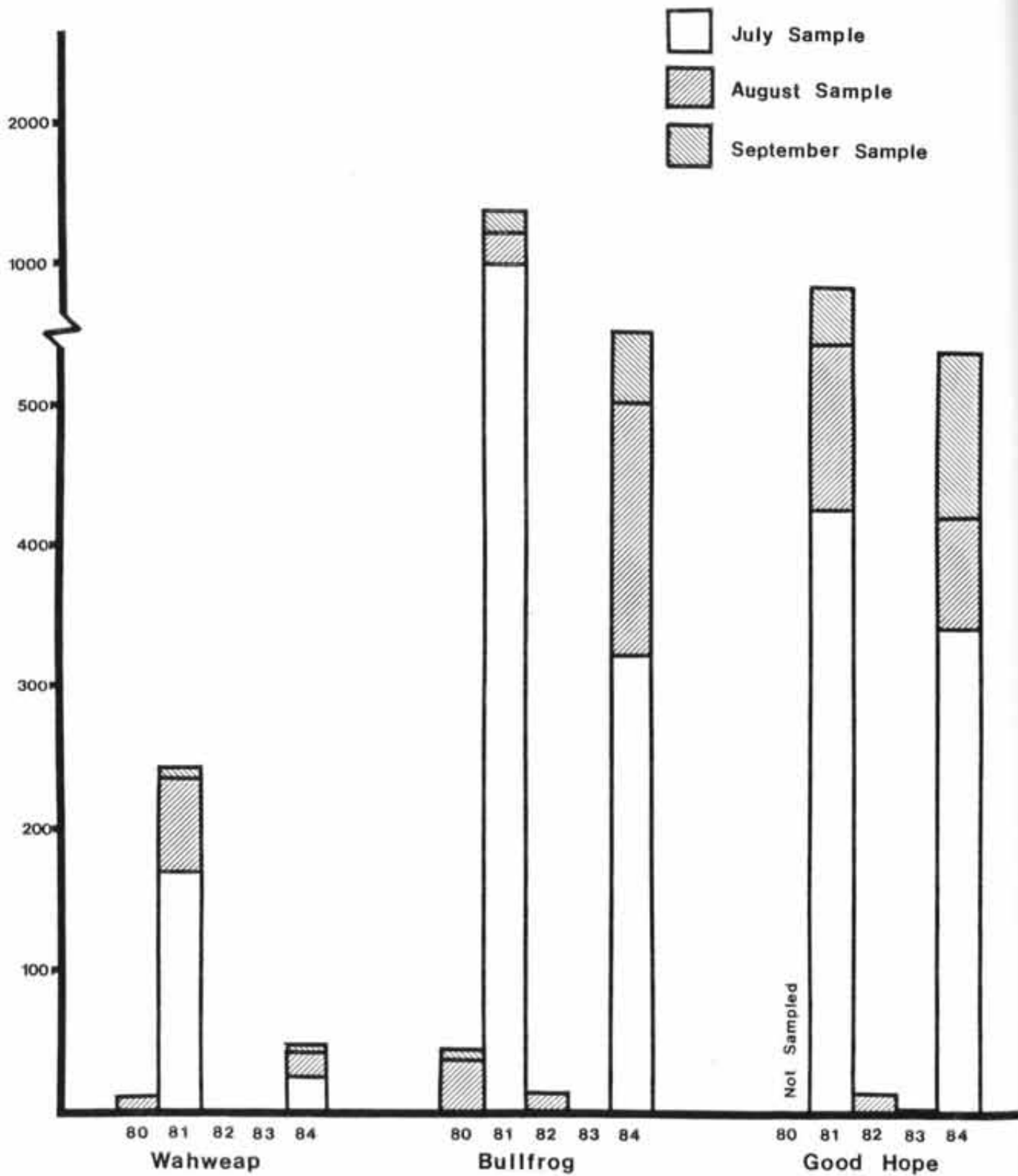


Figure 6. Mean number of shad collected per trawl tow, Lake Powell, 1980-1984. (The top of each bar represents the total catch for July-September for each year.)

three distinct peaks occurring at three year intervals; 1978, 1981 and 1984 (Figure 7). The two years between each peak have been characterized by very low shad recruitment in most areas of the lake. The high points and low points of the graph in Figure 7 do not, however, coincide with high and low production years revealed by the ichthyoplankton sampling (Figures 3, 4 and 5). Anderson (1973) found spawning was affected by density dependent factors, including crowding and nutritional conditions. It is possible that the cycling in numbers of y-o-y shad found in the pelagic zone of Lake Powell would have occurred regardless of the impact of predatory gamefish. Certainly during the first low point in Figure 7 (1979 and 1980) pelagic predators (i.e., striped bass) were not present in large numbers and would have had a negligible effect on shad populations (Job IV). Thus, density dependent factors may have caused the first observed crash (1979-80) in the shad cycle in Lake Powell but subsequent low points were probably exacerbated, at least in part, by predation.

Moczygemba and Morris (1977) reported that the open water zone is inhabited by surplus shad that are forced into the open water by intraspecific competition. Lack of shad in the pelagic zone is an indication of a predator-impacted shad population. The disparity between relatively high threadfin shad reproduction and subsequently low recruitment into the pelagic zones of Lake Powell probably resulted from striped bass predation.

Large year classes of striped bass have been produced since 1981 (Job IV) and may be causing the decreasing trend seen in the numbers of shad collected from the population peak years of 1978, 1981 and 1984 (Figure 7). Members of the large 1981-83 year classes of striped bass were also present in most locations where shad spawning occurred. Unlike the adult striped bass that must retreat to deeper, cooler water during the heat of summer (Job IV), the yearlings stayed in shallow water with the shad and fed heavily on both adults and y-o-y shad.

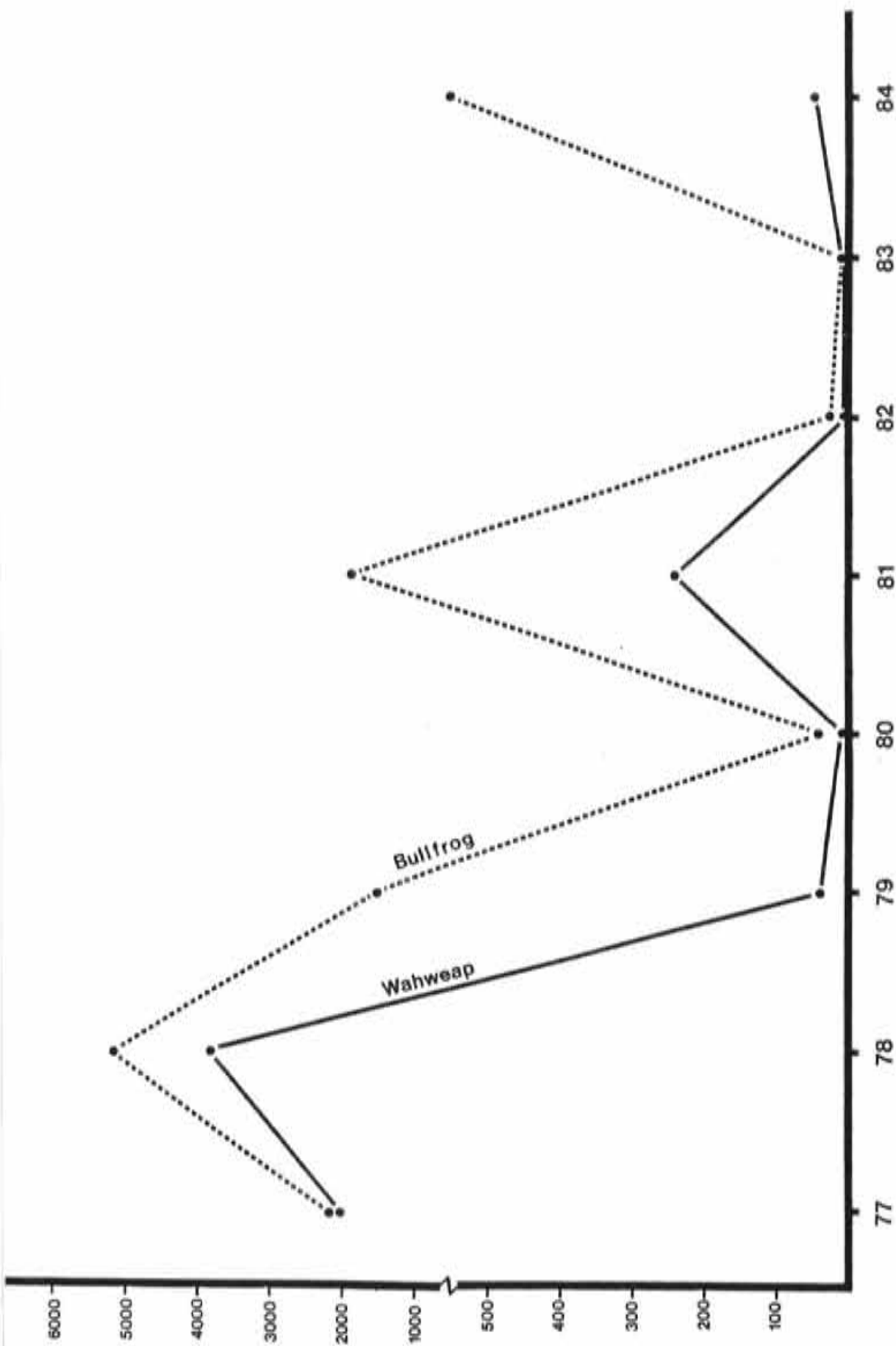


Figure 7. Mean number of threadfin shad collected per trawl tow, July-September, Lake Powell, 1977-1984.

In lake E.V. Spence, striped bass reduced the standing crop of gizzard shad and eliminated threadfin shad from the population (Morris & Follis 1978). Young gizzard shad that escaped predation grew rapidly. After exceeding the desired forage size preferred by striped bass (76-178 mm) they matured and spawned. Threadfin shad, because of their smaller size, were unable to outgrow the preferred prey size and were eliminated. Threadfin shad are the only schooling forage fish in Lake Powell and they support the striped bass population. Striped bass in Lake Powell presently have unlimited reproductive potential (Job IV). This has exerted a negative impact upon shad recruitment and may also be impacting the available brood stock in years of low shad populations.

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

Gustaveson et al. (1980) reported a winter shad die-off of unknown magnitude at Lake Powell during the winter of 1978-79. Water temperatures throughout the reservoir were near or below the critical 7.2C temperature for most of the winter. At that time it was felt that winter die-offs of shad could present a major problem to Lake Powell's shad population. Since 1979, there have been no reports of large numbers of dead shad found during the winter. A small number of dead shad were reportedly seen around the docks at Hite, Bullfrog and Hall's marinas by marina employees in February 1984, but it was never confirmed. There have been few times since 1979 that lake temperatures have fallen below 7C for extended periods.

SUMMARY AND RECOMMENDATIONS

Water temperatures at Lake Powell are probably optimum for maximum annual production of threadfin shad. In most years shad are able to begin spawning in May and continue into September. This fact alone could account for the ability of Lake Powell's shad population to rebound quickly (1-2 years) from population low points, whether they be caused by density dependent factors, predation or other causes. What factor(s) are responsible for the cycles observed in the lake's pelagic shad populations are somewhat unclear. It appears, however, that striped bass predation has been responsible for an overall reduction of shad numbers in the open water areas of Lake Powell.

Threadfin shad reproduction has been quite high in both 1983 and 1984. This allowed y-o-y shad to once again inhabit the pelagic zone of the lake in good numbers in 1984. Whether this condition will continue in 1985 or the shad population will again crash will be the subject of shad studies in 1985.

It is thus recommended to continue ichthyoplankton netting and midwater trawling as established during this reporting period. The ichthyoplankton netting has proven useful in monitoring seasonal and annual larval shad production, and the duration of the spawn. Midwater trawling has been useful in evaluating y-o-y shad recruitment into the pelagic zone of the lake as well as for monitoring trends of available forage for striped bass. The use of echosounding to add support to trawling data should also be continued. Echosounding has proven a valuable tool when equipment breakdowns have prevented trawl sampling. In addition, echosounding is presently the only effective technique for monitoring adult populations of threadfin shad in the winter.

Ichthyoplankton netting at Moki Canyon will be discontinued. The samples collected at Moki Canyon during 1984 do not add anything

unique to our understanding of shad reproduction in mid Lake Powell and only reflect the findings at Bullfrog and Hall's Creek.

Water temperatures should continue to be monitored during the winter months to assess any problems with shad die-offs. Although no major problem was observed during this reporting period, winter-time shad die-off has occurred previously at Lake Powell.

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 (Gustaveson et al. 1979, 1980, 1981, 1982, 1983). 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 highest catch rates occurring in the early 1970's. Black crappie and largemouth bass consistently comprised over 70 percent of the annual catch from 1970-1979. Since 1980, the striped bass fishery has gradually improved as the population increased.

METHODS

A scheduled creel census was conducted from April through September in 1981 and from April through October in 1982-1984. During 1980, the census was conducted during the three months of most intensive angler use - April through June. In 1984, a March creel census was conducted at Wahweap to obtain biological data and harvest information on striped bass from prespawning staging areas near the dam.

Anglers were interviewed as they returned to launching ramps at the four major access areas - Hite, Hall's Crossing, Bullfrog, and Wahweap. Due to the isolated nature of the reservoir and limited access, most anglers gained access at one of these four points. Historically, the Wahweap access area was censused an average of 10 days/month, while a total of 8-14 days/month were spent censusing anglers at Hite, Hall's Crossing, and Bullfrog. As angling pressure equalized between areas, the Wahweap census was reduced to 5

days/month while Bullfrog and Hall's Crossing were combined into one mid-reservoir area and surveyed a total of 6 days/month (3 days at each station). The Hite survey remained at 4 days/month. In 1984, all creel survey days were reduced from 8 hours to 4 hours. Census days for each access area were divided equally between weekdays and holidays/weekends. Data obtained during interviews of anglers included number and species of fish caught, time spent fishing, the number of anglers/boat, residence of anglers, location fished, and preferred species sought. Creel rates presented in this report were derived from all fishermen collectively. Since many Lake Powell anglers often camp out overnight and fish for several days at a time, data was collected from the fishermen for the census day, as well as for their previous day of fishing. Total length measurements, scales, and stomach samples were obtained from selected samples of game fish.

In 1983 a computer program was designed to summarize data collected from the creel survey and was used in 1983 and 1984. Pressure estimates used in the program were based on the total number (fishing and nonfishing) of boat days and the percentage of total boat days which included angling activity. The total number of boat days was provided by the National Park Service and was calculated from (1) daily boat trailer counts at launch ramp and marina parking lots; (2) number of rental boats used each day; and (3) number of boats being used from local boat storage lots. The percentage of fishing boats was estimated for each month and access area from creel census interview data. Since fishing pressure from November-March represents only a small portion (13 percent) of annual pressure (Gustaveson et al. 1979), creel surveys were not conducted during these months. Limited, random interviews during this time revealed that approximately 75 percent of all boats were involved in fishing activity. This arbitrary figure was subsequently used to calculate fishing pressure from November-March.

RESULTS AND DISCUSSION

In 1984, a total of 3,098 boating parties was checked by creel clerks during the eight month census period. Of these, 1,058 (34 percent) reported angling activity. The mean number of anglers per fishing boat was 2.5 and each angler spent an average of 4.0 hours fishing per day (Table 6).

While angling pressure decreased on Lake Powell in 1984, recreational boat use increased (Figure 8). Angling pressure was 96,859 fishing boat days in 1984, a decrease of 2 percent from 1983. Total recreational boat use (including fishing and nonfishing boats) was 318,554 compared to 266,364 boat days in 1983. Bullfrog access area accounted for the highest angler use (42 percent) of the four major access points, while angler use at Wahweap, Hall's Crossing, and Hite access points was 36 percent, 14 percent, and 8 percent, respectively. This use trend has prevailed throughout the 1980-1984 period. Prior to 1980, Wahweap access area accounted for the highest angler use at Lake Powell.

The majority of anglers fishing at Lake Powell during the 1980-1984 census period were from Utah, Arizona, and Colorado. Almost all of the anglers censused at Bullfrog and Hite were from Utah and Colorado (Figure 9). More than 75 percent of the anglers at Hall's Crossing were from Colorado and New Mexico, while most of the anglers interviewed at Wahweap were from Arizona.

Most specific angling pressure in 1984 was directed at largemouth bass and striped bass (Table 7). The majority of the fishermen, however, were indiscriminate anglers or those willing to creel any fish that was captured. The percentage of anglers choosing to fish specifically for black crappie has steadily declined during the past 5 years to the current low point of 2.4 percent.

Table 6. Fishing boat use (boat-days) by month, Lake Powell, 1975-84. Also given are the average time (hr) fished/trip (H/T) and the mean number of fishermen/boat (F/B).

Year	Jan.	Feb.	Mar.	Apr.	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
1980	238	606	3,647	10,688	19,832	15,014	5,743	6,116	7,469	5,717	2,593	742	78,405	4.0	2.6
1981	817	1,279	4,681	9,495	14,033	13,772	11,886	11,092	12,440	6,166	3,545	833	90,039	4.0	2.5
1982	408	656	3,094	16,894	19,714	15,097	8,719	8,955	11,128	17,514	6,970	1,407	110,556	3.9	2.5
1983	668	768	3,996	12,655	23,008	13,475	8,999	8,383	10,076	7,522	7,522	1,292	98,550	4.9	2.6
1984	254	636	2,675	14,768	12,865	17,463	8,136	10,185	11,086	8,956	8,077	1,758	96,859	4.0	2.5
Ave.	430	916	3,732	12,495	15,634	11,824	6,879	7,025	8,021	6,866	3,788	874			
f	0.5	1.2	4.8	15.9	19.9	15.1	8.8	9.0	10.2	8.7	4.8	1.1			

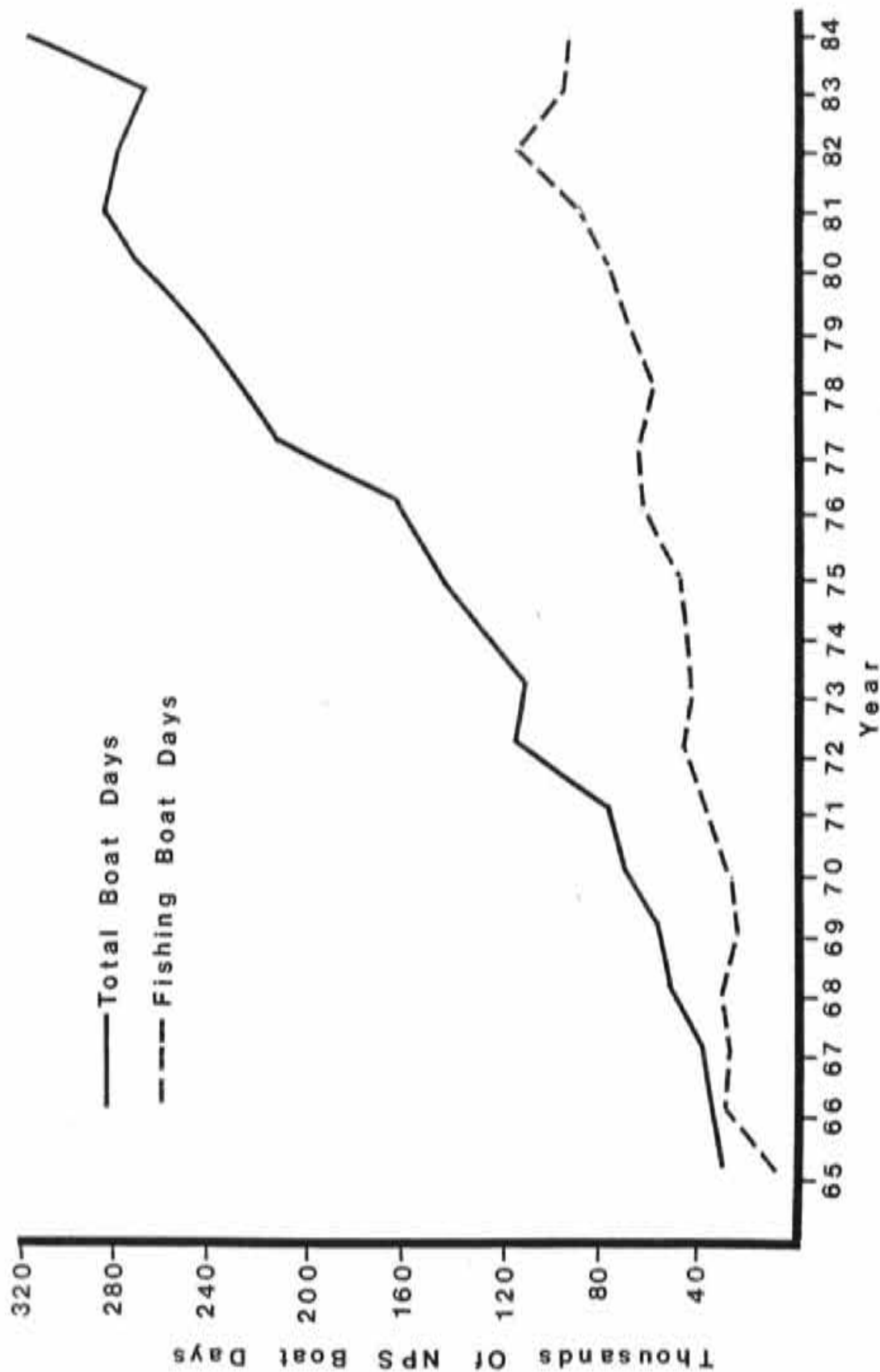


Figure 8. Indices of total recreational boat use and angling pressure, Lake Powell, 1965-1984.

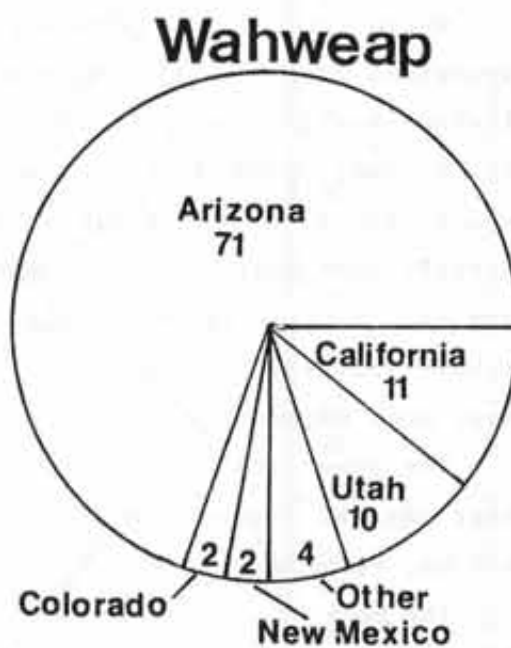
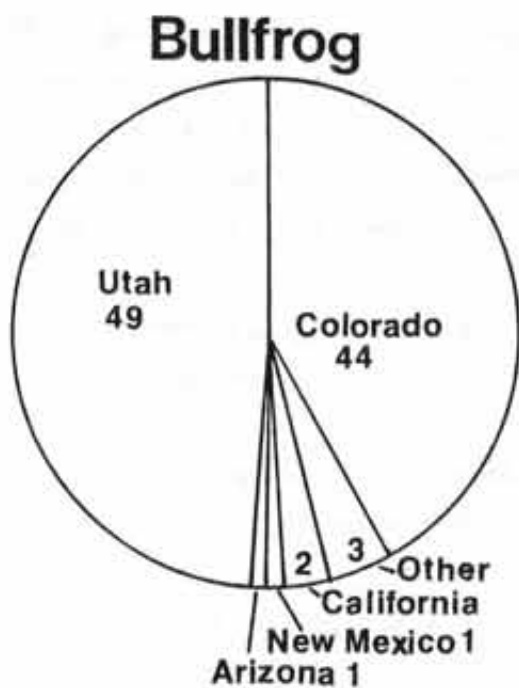
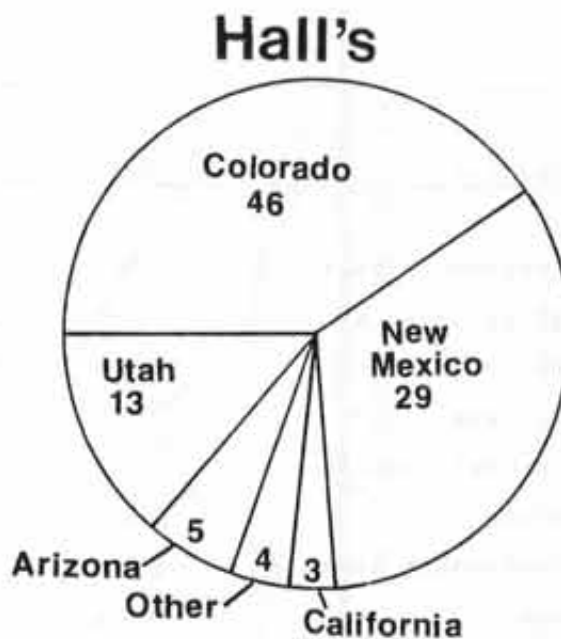
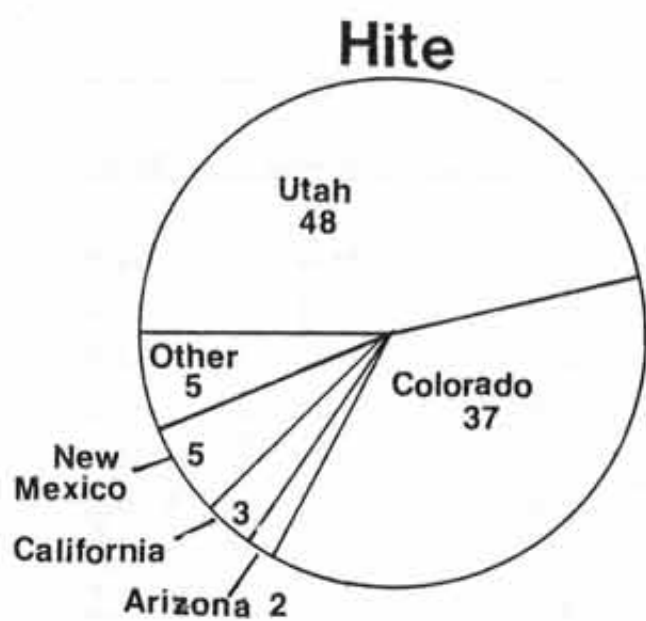


Figure 9. Residence of anglers using Lake Powell by access area, 1980-1984.

Table 7. Species sought (%) by anglers, Lake Powell, April-October 1984

Species	Hite	Bullfrog/Hall's	Wahweap	Total
Largemouth bass	48.8	25.8	33.4	34.7
Black Crappie	4.0	1.7	0.5	2.4
Striped bass	10.6	14.1	20.1	13.3
Walleye	0.5	1.9	0.4	1.3
Channel catfish	0.7	0.4	1.3	0.6
Bluegill	0.0	0.4	0.5	0.3
Smallmouth bass	0.0	0.0	0.2	c ^a
Any	35.4	55.7	43.6	47.4

^a = less than 0.1%

While creel rates (fish/angler hour) for largemouth bass (0.052) increased slightly in 1984, a slowly declining trend has been established over the past five years (Figure 10). Creel rates for both black crappie and for all species combined have decreased annually since 1980. For the first time since striped bass were introduced, striped bass anglers in the upper (Hite) and mid-reservoir (Bullfrog and Hall's Crossing) had higher success than those in the lower reservoir (Wahweap) (Table 8 and Table 9). Those fishing for walleye were most successful at mid-reservoir (Table 8).

The mean lengths of largemouth bass, black crappie, and striped bass checked during creel census in 1984 were 347 mm, 265 mm, and 498 mm, respectively.

The bulk of the fishery in 1984 was supported by largemouth bass (34.3 %), while black crappie (18.0 %) were also seasonally important (Table 10). Striped bass also made up a large portion (14.9 %)

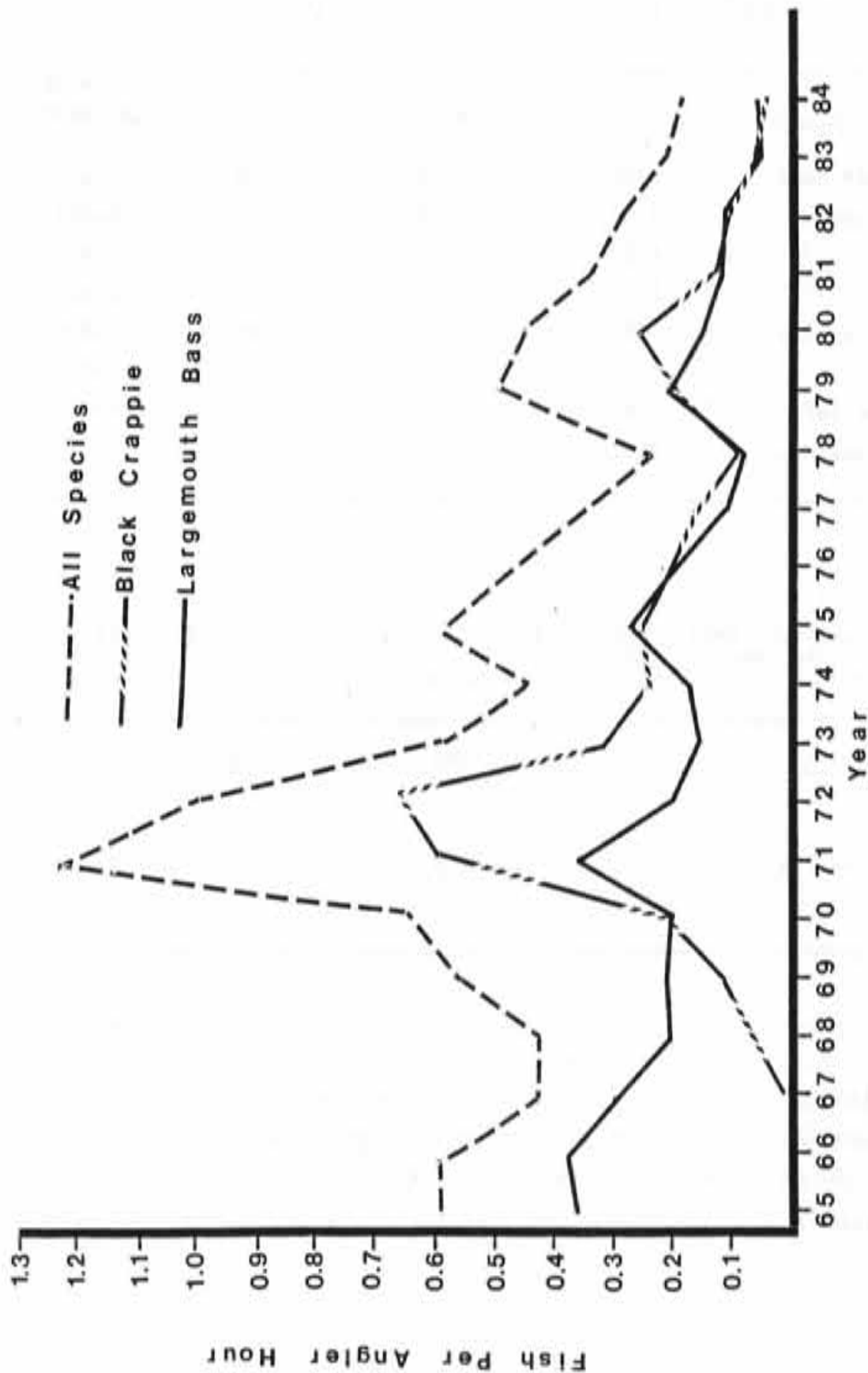


Figure 10. Creel rates (fish/angler hour) for largemouth bass, black crappie and all species, Lake Powell, April-June 1965-1984.

Table 8. Sport fishery creel rates (fish/angler hour) by species and access area, Lake Powell, April-October 1984.

Species	Hite	Bullfrog/Hall's	Wahweap	Lakewide Average
Largemouth bass	0.062	0.044	0.070	0.052
Black crappie	0.032	0.027	0.032	0.029
Striped bass	0.024	0.032	0.023	0.029
Walleye	0.007	0.033	0.009	0.022
Channel catfish	0.020	0.019	0.025	0.020
Bluegill	0.008	0.030	0.036	0.023
Other species	0.002	0.003	0.002	0.002
All species	0.155	0.187	0.196	0.176

Table 9. Striped bass creel rates (fish/angler hour) by access area Lake Powell, 1980-1984

Location	1980	1981	1982	1983	1984
Hite	0.002	0.005	0.015	0.023	0.024
Bullfrog/Hall's	0.004	0.008	0.026	0.031	0.032
Wahweap	0.007	0.034	0.083	0.154	0.023

of the fishery throughout most of the season. Walleye made up the largest portion of the catch in June (36.2 %) and a substantial portion (9.7 %) of the harvest in May (Table 10).

Table 10. Species composition (%) of the total creel, Lake Powell, March-October 1984.

Species	Mar ^a	Apr	May	Jun	Jul	Aug	Sep	Oct	Mean
Largemouth bass	57.7	34.0	31.7	15.4	58.4	16.5	29.8	31.3	34.3
Black crappie	35.9	47.6	18.3	3.6	18.1	9.1	1.0	10.1	18.0
Striped bass	3.8	6.1	12.9	23.9	3.5	25.9	19.4	23.6	14.9
Walleye	1.3	2.9	9.7	36.2	8.3	3.4	0.2	5.2	8.4
Channel catfish	0.0	2.4	6.1	16.8	8.8	25.1	20.9	6.4	10.8
Bluegill	0.0	6.1	19.2	3.6	1.9	20.0	27.7	20.8	12.4
Other	1.3	0.9	2.1	0.5	1.0	0.0	1.0	2.6	1.2

^a March creel conducted at Wahweap only.

The first confirmed occurrence of lake trout (Salvelinus namaycush) in Lake Powell was recorded during creel census in May 1983. Another was netted by a Bureau of Reclamation biologist in April 1984 and a third was caught from Bullfrog Bay in December 1984. All three fish probably migrated downstream from either Flaming Gorge Reservoir, Utah, or Blue Mesa Reservoir, Colorado.

In spite of the growing sophistication of the Lake Powell bass anglers, catch rates of largemouth bass have continued to decline over the past five years. Many bass anglers now use complex and expensive equipment, including electric trolling motors, depth sounders and fish finders, electronic temperature and pH gauges, and other gadgets. While use of this gear does not guarantee fishing success, the anglers versed in operation and application of this equipment generally catch more fish than those without it. The reduced catch rates reported at Lake Powell over the past few years are mainly the result of decreasing populations of largemouth bass. Indices of abundance for catchable-size largemouth bass have shown

substantial correlation with angler success at Lake Powell, especially since 1979 (Job III). It appears that the once booming largemouth bass fishery that existed shortly after impoundment has declined to a less successful fishery, a pattern common to many aging reservoirs (Hashagen 1973, and Jenkins 1968).

The striped bass creel limit was increased from 4 to 10 fish in 1984, yet harvest of striped bass declined substantially from 1983, especially in the Wahweap area. Following striped bass spawning in May 1983, a buoy-line was installed by the U.S. Bureau of Reclamation to exclude boats from approaching the dam. In 1984, therefore, fishermen were barred from congregations of prespawning striped bass which staged at the dam and were quite vulnerable to angling. This has effectively eliminated a highly successful spring fishery and probably contributed to the decrease in harvest of striped bass in 1984. Additionally, the relative abundance of adult striped bass was probably less in 1984 than in 1983 (Job IV).

Prior to 1980, the bulk of the striped bass fishery in Lake Powell was in the lower portion of the reservoir. Since then, striped bass have become established lakewide. Subsequently the creel rate and harvest of this species has increased substantially in the middle and upper reservoir.

Many anglers are now versed in the techniques necessary to effectively harvest striped bass, and in 1983 an exceptional striped bass harvest exceeded that of all other species in Lake Powell. The striped bass fishery is well accepted by most anglers and provides a trophy fishery as well as an abundant fishery that less experienced anglers can enjoy.

SUMMARY AND RECOMMENDATIONS

While angler creel rates for largemouth bass and black crappie have decreased annually over the past five years, striped bass creel rates have increased. As a result, a large portion of anglers

have become opportunists and fish for whatever they can catch. Some fishermen still primarily pursue largemouth bass. Striped bass have been highly accepted by anglers and have become an important component of the Lake Powell fishery. Future creel surveys should continue to closely monitor the dynamic striped bass fishery as well as the other Lake Powell sport fisheries.

Recent introductions of smallmouth bass will also be monitored with the creel survey. As the smallmouth bass fishery expands in Lake Powell, the creel census should be a useful method of obtaining the biological data needed to make correct management decisions.

In recent years, the mid-reservoir access areas have had the highest use by fishermen. The addition of a Bullfrog-Hall's Crossing car ferry in the summer of 1985, as well as future plans to pave the Burr Trail road should further increase visitation rates and fishing pressure at the mid-reservoir access areas.

INDEX TO ANNUAL POPULATION TRENDS

JOB III

ANNUAL NETTING

BACKGROUND

Standardized gillnet sampling has been used to describe gross changes in fish population densities and species composition at Lake Powell. Standardized gillnet sampling has been conducted annually since 1971 (Gloss et al. 1974; May and Hepworth 1976; Gustaveson et al. 1980, 1981, 1982, 1983, 1984). The gillnet sampling has been most effective in describing changing trends in the largemouth bass and walleye populations. The largemouth bass population was most abundant during the early 1970's and has generally declined since that time. During the same period walleye abundance has generally increased.

The survey has been quite sensitive in detecting the presence of new species and illustrating the decline of others. Rainbow trout were an important sport fish in the 1960's and early 1970's; however, trout stocking was discontinued when striped bass were introduced in 1974. The survey depicted the decline of trout abundance and the subsequent increase in striped bass numbers (Gustaveson, et al. 1980).

METHODS

Gillnet sampling was conducted during March 1980-84 at Padre Bay, the San Juan Arm, the Rincon, and Good Hope Bay (Figure 11). Gangs of ten 30.5 m diving experimental gillnets with four 7.62 m

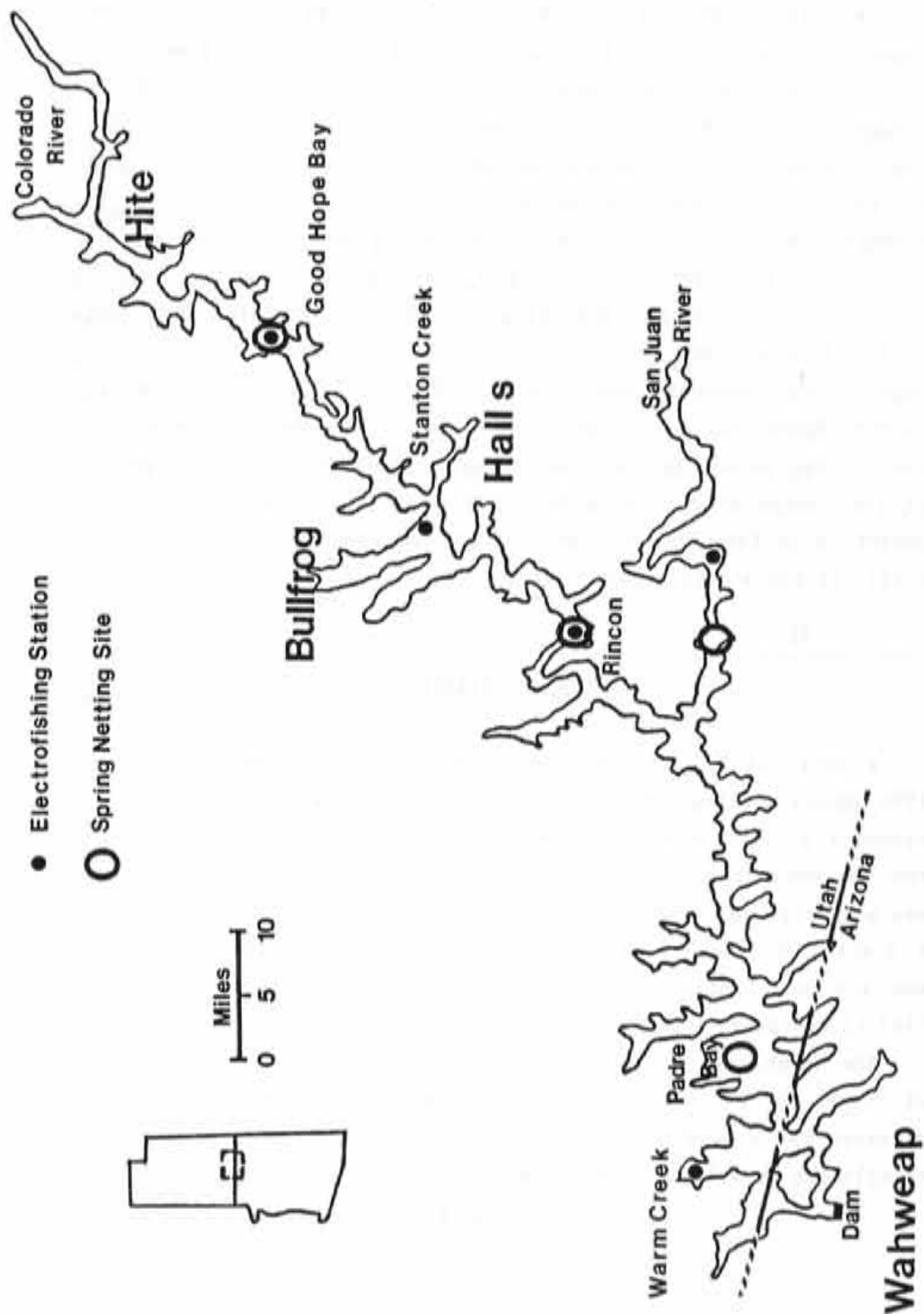


Figure 11. Map of Lake Powell, Utah-Arizona, showing annual netting sites (dots) and electrofishing transects (circles).

panels (mesh sizes 25, 38, 51, and 76 mm) were fished for three consecutive days at each station. On occasion, fewer nets were used due to net loss or damage while sampling. Nets were set perpendicular to the shore with one end anchored to the shoreline. The nets were set on the bottom, in similar talus rock and rubble habitat. Fish were removed at 24-hour intervals, weighed and measured, and scales were taken for age and growth analysis.

A selected sample of walleye and largemouth bass was used to quantify fish condition according to the UDWR Visceral Fat Index (VFI) (Ronald Goede, Fish Pathologist, UDWR Experiment Station, Logan, Utah, personal communication, 1980). Fish were assigned categories depending on the amount of visceral fat found on the pyloric caeca. The categories were as follows: 0=no fat; 1=less than 50% of the caecum covered with fat; 2=approximately 50% of the caecum covered with fat; 3=more than 50% of each caecum covered with fat; 4=pyloric caeca completely covered with fat.

RESULTS AND DISCUSSION

A total of 522 fish was collected in 120 net days during the 1984 annual netting. The highest catch rate (6.17 fish/net day) was recorded at Good Hope Bay, followed by the Rincon, Padre Bay, and the San Juan, respectively (Table 11). The overall catch for 1984 was slightly higher than 1983 at all stations except Padre Bay where a small reduction occurred. The total catch rate for all species and stations combined (4.35 fish/net day) increased slightly from 1983 (3.68 fish/net day) (Table 12).

The catch rate of largemouth bass continued to decrease in 1984 as it has for the past six years (Figure 12). However, the rate of decrease has slowed and the largemouth bass population seems to be stabilizing at a lower relative abundance than seen historically.

Table 11. Catch rates (fish/net day) during annual spring gill-netting, Lake Powell, March 1984.

Species	Padre Bay	San Juan	Rincon	Good Hope Bay	Total ^a	% of Catch
Largemouth bass	0.33	0.67	0.33	0.50	0.46	10.6
Walleye	2.53	1.03	1.53	3.97	2.26	52.0
Striped bass	0.07	0.30	2.53	0.67	0.89	20.5
Black crappie	0.00	0.03	0.00	0.00	0.01	0.2
Carp	0.13	0.30	0.53	0.50	0.37	8.5
Channel catfish	0.03	0.13	0.30	0.30	0.19	4.4
Green sunfish	0.00	0.07	0.13	0.17	0.09	2.1
Bluegill	0.13	0.00	0.00	0.10	0.05	1.1
Brown trout	0.00	0.03	0.00	0.00	0.01	0.2
Flannelmouth sucker	0.00	0.00	0.07	0.00	0.02	0.5
Total	3.23	2.57	5.43	6.17	4.35	--

^a Total = total number of fish divided by total net days.

Table 12. Catch rate (fish/net day) by species and year, annual gillnetting, Lake Powell, 1971-84.

Species	Catch Rate													
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Largemouth bass	1.65	5.82	2.71	4.01	4.49	2.72	1.85	2.61	1.83	1.57	1.41	0.63	0.47	0.46
Walleye	0.29	1.12	0.41	1.09	2.15	2.11	1.17	2.84	3.25	3.66	4.99	2.17	1.73	2.26
Striped bass	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.09	0.02	0.24	0.13	0.32	0.89
Black crappie	0.12	0.67	0.12	0.27	0.36	0.27	0.26	0.33	0.21	0.03	0.16	0.08	0.04	0.01
Bluegill	0.12	0.52	0.06	0.05	0.04	0.10	0.09	0.04	0.03	0.01	0.05	0.02	0.01	0.05
Green sunfish	0.10	0.16	0.09	0.13	0.06	0.04	0.09	0.10	0.10	0.02	0.07	0.05	0.02	0.09
Channel catfish	0.12	0.43	0.21	0.14	0.25	0.16	0.20	0.29	0.38	0.36	0.17	0.04	0.27	0.19
Carp	1.14	0.79	0.32	0.34	0.36	0.38	0.44	0.34	0.32	0.32	0.55	0.49	0.79	0.37
Flannelmouth sucker	0.18	0.28	0.21	0.17	0.08	0.08	0.03	0.03	0.04	0.06	0.04	0.00	0.01	0.02
Rainbow trout	0.24	0.31	0.10	0.08	0.19	0.25	0.26	0.11	0.04	0.02	0.01	0.00	0.00	0.00
Brown trout	0.02	0.00	0.01	0.03	0.04	0.04	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.01
Yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.03	0.03	0.03	0.02	0.02	0.00
All species	3.98	10.10	4.24	6.31	8.02	6.15	4.44	6.82	6.32	6.12	7.73	3.62	3.68	4.35

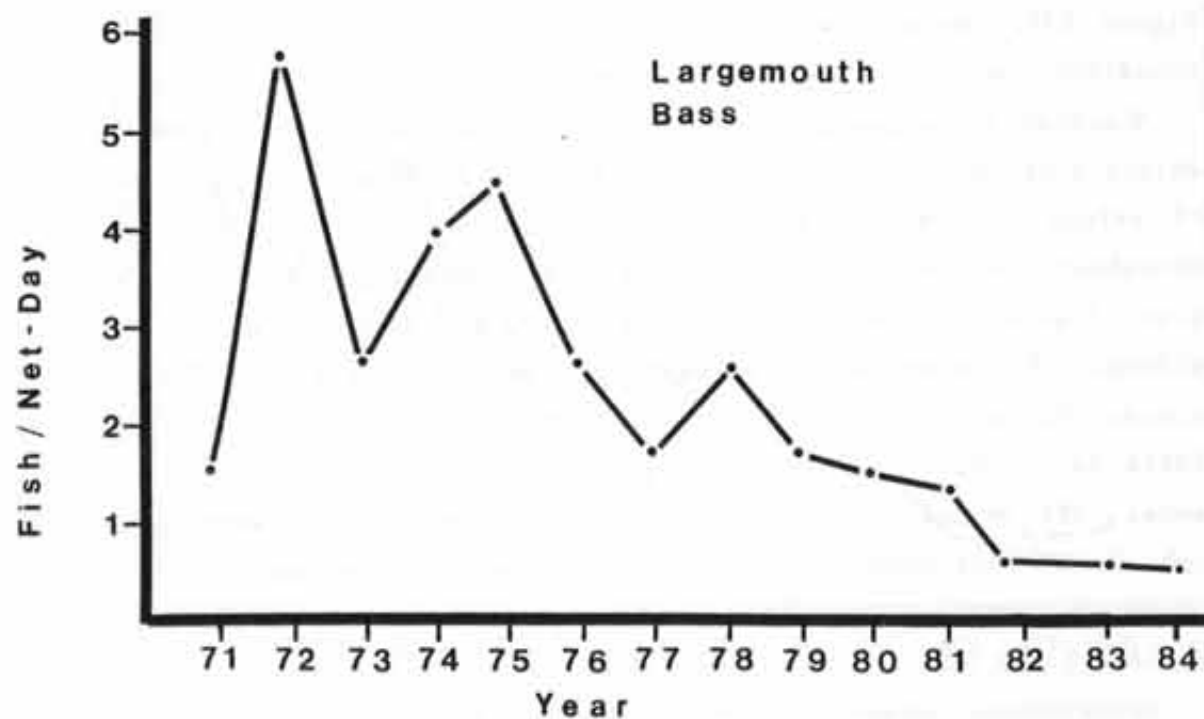
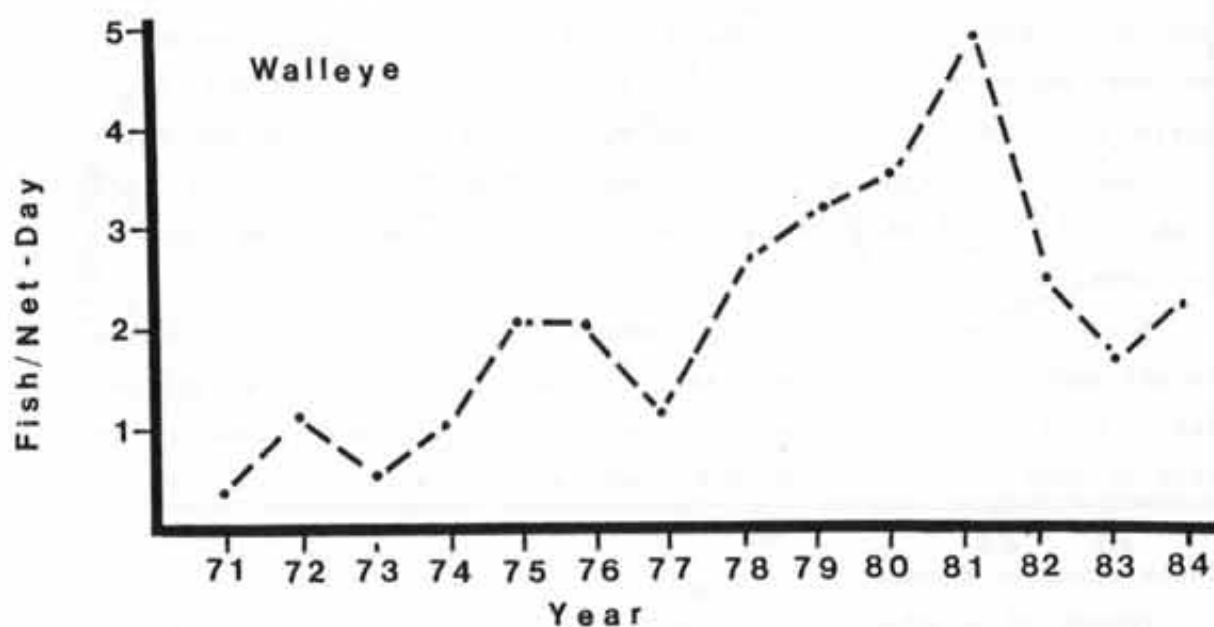


Figure 12. Catch rates (fish/net day) for walleye and largemouth bass from annual netting, Lake Powell, 1971-1984.

The catch rates for both walleye and striped bass increased slightly in 1984. Between 1971 and 1981, walleye catch rates generally increased suggesting that the population expanded during that period (Figure 12). Substantial reductions in catch rates of walleye occurred in 1982-83, however, the walleye gillnet catch again increased in 1984. Striped bass catch rates have generally increased since they were first recorded in the survey in 1977 (Table 12). Striped bass catch rates in 1984 were second only to walleye.

Black crappie, carp, and channel catfish were occasionally caught and collectively comprised 13.1 percent of the total gillnet catch in 1984. These species have shown no apparent changes in density over the past five years and are probably not sampled by this survey in large enough numbers to make inferences concerning their relative abundance.

Trends of abundance in the gillnet survey appear to follow the annual trends in creel rates for both walleye and largemouth bass (Figure 13). Both surveys appear equally effective in describing population trends for these two species and complement one another.

Visceral Fat Index (VFI) values indicated that walleye normally exhibit a value of around 2.9 (Table 13). A trend of slightly lower VFI values for walleye captured in the lower reservoir persisted throughout the sampling. Largemouth bass normally exhibit a VFI value of about 1.5, which is considerably lower than VFI values for walleye. VFI values for largemouth bass dropped over a full "point" between 1981 and 1982 and have remained low for the past three years (Table 14). VFI appeared to be influenced by threadfin shad abundance. VFI values for both walleye and largemouth bass were quite high at the beginning of 1981, but following a decrease in shad abundance in 1981 (Job I), VFI values dropped considerably (Tables 13 and 14).

Correlations between VFI and condition factors (K) were statistically analyzed for both walleye and largemouth bass. While some correlation existed, linear regression values for both walleye (0.22) and largemouth bass (0.13) were low in 1984.

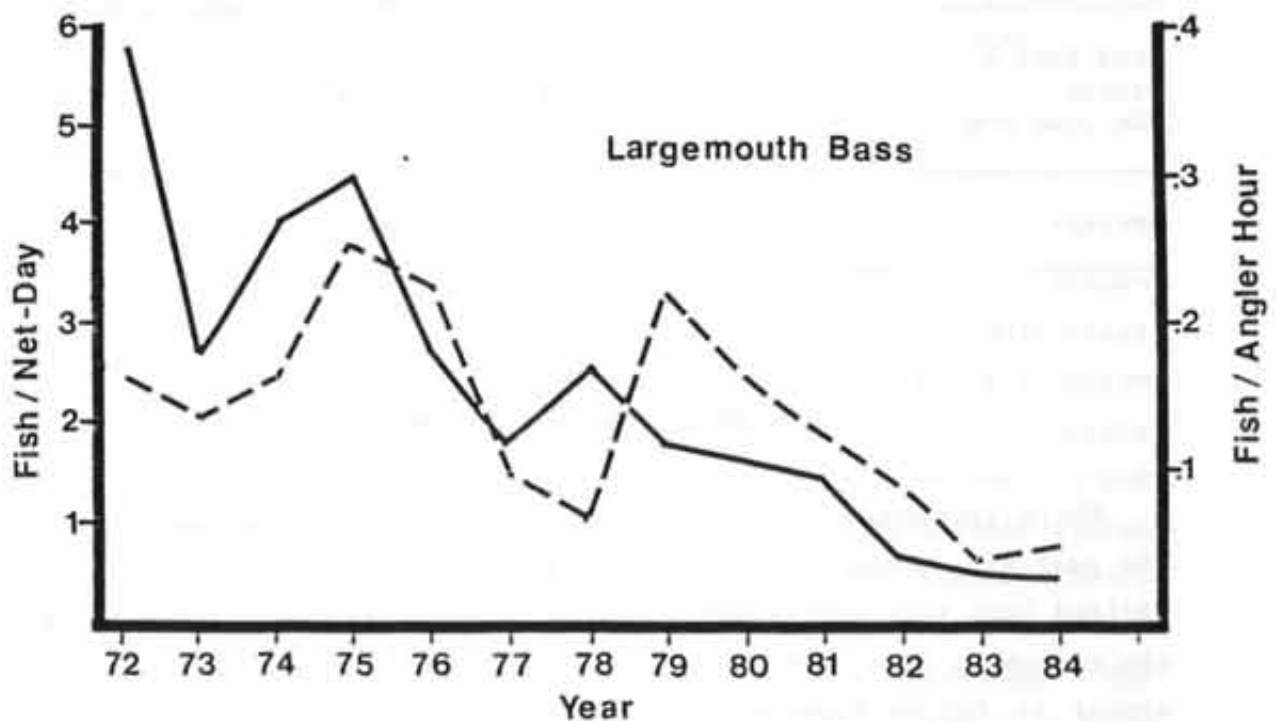
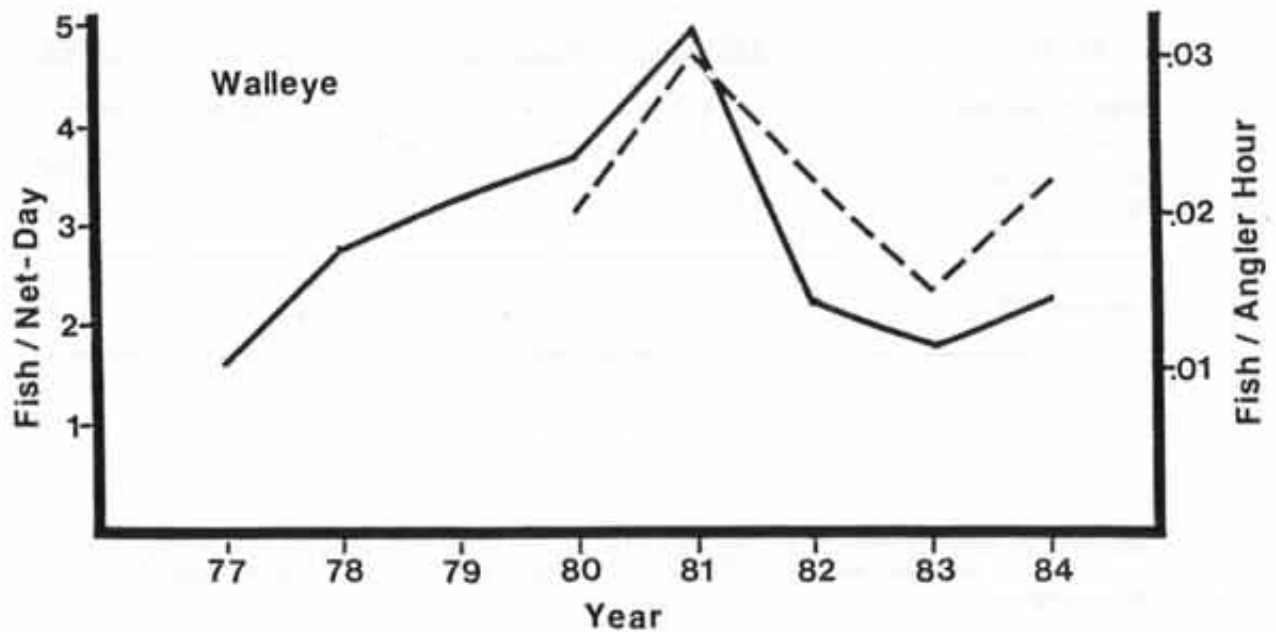


Figure 13. Relationship of gillnetting catch rates (solid line) and creel rates (dashed lines) of walleye and largemouth bass collected at Lake Powell, 1972-1984.

Table 13. Mean visceral fat index (VFI) values for walleye collected by gillnetting during 1980-84, Lake Powell.

Location	1980	1981	1982	1983	1984
Good Hope Bay	3.5	3.5	3.0	2.8	3.7
Rincon	3.3	3.6	2.8	3.3	2.6
San Juan Arm	-	3.4	2.6	2.3	2.7
Padre Bay	2.8	1.9	1.9	2.2	2.9
Average VFI	3.2	3.1	2.5	2.7	3.0

Table 14. Mean visceral fat index (VFI) values for largemouth bass collected by gillnetting during 1980-84, Lake Powell

Location	1980	1981	1982	1983	1984
Good Hope Bay	2.3	2.8	1.2	0.6	1.2
Rincon	-	2.3	1.6	0.7	0.4
San Juan Arm	-	-	1.0	-	1.1
Average	2.1	2.4	1.3	0.7	1.0

SUMMARY AND RECOMMENDATIONS

While largemouth bass catch rates have decreased annually over the past five years, walleye catch rates have remained fairly high. Striped bass were infrequently caught in the past but more recently their numbers have been increasing. Results of the gillnet survey appear to follow fishermen success quite closely for walleye and largemouth bass fishermen. Therefore, the survey is very useful in

following population trends of these species, as well as other game fish found in Lake Powell. Continued use of the gillnet survey to describe population trends of established game fish, as well as recently introduced species, is thus recommended.

Baseline VFI values have been established for walleye (2.9) and largemouth bass (1.5) in Lake Powell.

ELECTROFISHING

BACKGROUND

An annual program of electrofishing was initiated in 1977 to obtain information on the relative abundance of y-o-y largemouth bass and black crappie which were inadequately sampled by gillnets. More recently, the survey has become important in acquiring information on trends of striped bass and smallmouth bass production.

METHODS

The electrofishing boat was a 8.5 m Yukon Delta with a fiberglass hull. In 1980, an Onan 7.5 kw generator provided electrical power for the lighting system and a Coffelt Model RF-10 electroshocker. In 1981, the electroshocker was replaced with a Coffelt Model VVP-15 which was used through 1984. The modifications did not visibly alter the effectiveness of the unit. The electrode system used was similar to that described by Novotny and Priegel (1974). The positive array consisted of two 1.0 m diameter hoops of EMT electrical conduit, each with five to seven dropper electrodes. The negative electrodes were 2.0 m long sections of 13 mm cable, with three on each side of the boat. The output to the entire positive array was 8-12 a and 150-200 v dc with a pulse rate of 80/second and a pulse width of 60 percent.

Five shoreline transects (Warm Creek, San Juan, Rincon, Bullfrog and Good Hope Bay) were sampled each year (Figure 11). Similar shoreline habitat was electrofished at each transect. Transect locations have been altered slightly to include a greater portion of the reservoir and to conform more closely with the spring gill-netting sites. Water conductivity at all transects ranged from 400-600 micromhos/cm.

The sampling crew consisted of a boat operator and two netters. In 1980-81, the survey involved two nights of sampling for a total of 1-1/2 hours electrofishing time at each station. Sampling was reduced to one night for 1 hour electrofishing in 1982-84. Electro-fishing time included only that time in which the shocking system was engaged and the time was measured with a stopwatch. Four 15 minute timed transects were conducted at each station. Following each 15 minute session, captured fish were measured to the nearest mm and released at the capture site. Fish per hour totals are a summation of all fish captured during the four 15 minute sessions at each station.

RESULTS AND DISCUSSION

A total of 2500 fish was collected during the 5 nights of electrofishing in 1984. Catch rates for all species were highest at Good Hope Bay, followed by Stanton Creek, the Rincon, the San Juan, and Warm Creek, in descending order (Table 15). A trend of higher catch rates at the more highly productive inflow area and declining rates with progression downstream was observed. The mean catch rate for all species at Good Hope Bay was nearly double last year's catch rate but was primarily due to the substantial increase in catch of y-o-y channel catfish (Ictalurus punctatus) (50 percent of the catch) which only occurred in the upper reservoir. While Warm Creek showed a slight increase, the remaining three stations showed lower catch rates than seen in 1983.

Table 15. Mean catch rate^a (fish/hour) of fish collected by electrofishing, Lake Powell, September 1984.

Species	Good Hope Bay	Stanton Creek	Rincon	San Juan	Warm Creek	% of Total Catch
Young-of-the-year largemouth bass	52	47	66	29	72	10.6
Age I and older largemouth bass	14	8	12	12	2	1.9
Young-of-the-year black crappie	25	3	0	0	0	1.1
Young-of-the-year striped bass	62	4	7	1	0	3.0
Channel catfish	677	23	20	30	7	30.3
Green sunfish	52	99	68	204	5	17.2
Bluegill	281	194	156	47	170	33.9
Young-of-the-year smallmouth bass	0	5	0	0	46	2.0
All species	1163	383	329	323	302	---

^a Total fish divided by total hours of electrofishing.

The lakewide catch rate of y-o-y largemouth bass in 1984 decreased for the second consecutive year (Figure 14). Recruitment of black crappie was extremely limited as no fish were collected at three of the five stations (Table 15). The lakewide average catch rate of y-o-y black crappie in 1984 (6 fish/hour) was the lowest since the initiation of the electrofishing survey, with the exception of 1981 when only 1 fish/hour was collected (Table 16). While the average catch rate for y-o-y striped bass decreased in 1984, production has been generally increasing since they were first

sampled in 1980. As in 1984, striped bass have been historically collected at higher rates in the upper reservoir than in the middle and lower reservoir. Average lengths of y-o-y largemouth bass, striped bass, and smallmouth bass collected in 1984 were 97 mm (N=257), 66 mm (N=64), and 77 mm (N=51), respectively.

Table 16. Mean catch rate^a (fish/hour) of fish collected by electrofishing, Lake Powell, 1980-84.

Year	1980	1981	1982	1983	1984
Young-of-the-year largemouth bass	128	21	153	61	53
Age I and older largemouth bass	8	7	9	15	10
Young-of-the-year black crappie	135	1	13	39	6
Young-of-the-year striped bass	1	17	4	40	15
Channel catfish	24	9	9	9	151
Green sunfish	195	137	67	177	86
Bluegill	302	160	41	195	170
Young-of-the-year smallmouth bass	0	0	4	0	10
Age I and older smallmouth bass	0	0	0	1	0
All species	797	353	300	535	500

^a Total fish divided by total hours of electrofishing.

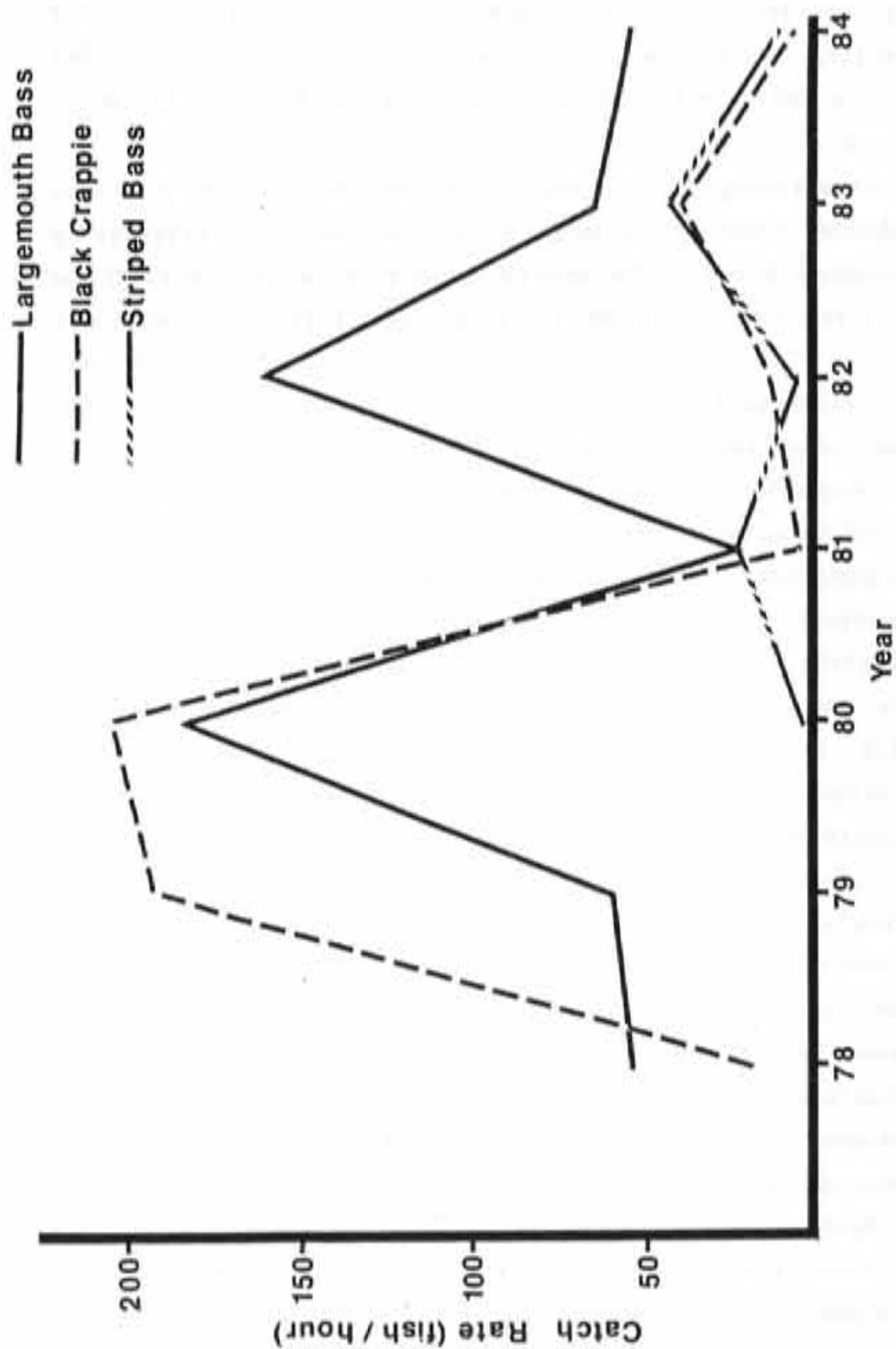


Figure 14. Mean catch rates (fish/hour) for largemouth bass, black crappie and striped bass collected by electrofishing, Lake Powell, August-September, 1978-1984.

SUMMARY AND RECOMMENDATIONS

Catch rates of y-o-y largemouth bass, black crappie, and striped bass have all decreased in 1984. Black crappie catch rates showed a dramatic decline in 1981 and have remained low since then. Striped bass production over the past five years has shown a gradually increasing trend.

The electrofishing survey should be continued to help assess relative abundance of y-o-y game fish that are not effectively sampled by other means. The survey is particularly important in describing abundance trends of y-o-y striped bass and smallmouth bass.

MONITORING OF STRIPED BASS POPULATION DEVELOPMENT

JOB IV

BACKGROUND

Striped bass fingerlings were stocked into Lake Powell annually from 1974-1979. Approximately 80 percent of the fish were released into Wahweap Bay near Glen Canyon Dam. Natural reproduction was first detected in the mid and upper reservoir in 1979, at which time stocking was curtailed so impact of natural reproduction could be fully evaluated. Young-of-the-year striped bass were confined to the upper reservoir in 1979 and 1980 and were presumed to be the result of spawning in the Colorado River above Lake Powell. However, spawning congregations of mature striped bass were also present in the lower reservoir at this same time. Collection of y-o-y striped bass near Glen Canyon Dam in 1981 indicated striped bass had successfully spawned within the reservoir despite the absence of turbulent current to suspend the eggs (Gustaveson et al. 1984).

Striped bass introduced in the 1970's readily adapted to their new environment. Growth was rapid with little intraspecific competition and an abundant underutilized shad population. A significant sport fishery emerged in 1979, coinciding with striped bass sexual maturity. The sport fishery peaked in 1982-1983 when the large population of mature striped bass and low shad numbers combined to produce excellent angling for hungry striped bass. During 1982-83, however, this first generation of stocked striped bass declined in physical condition and were drastically reduced in number. This was due to lack of shad forage, angling harvest and natural mortality. A relatively few older individual fish have survived and attained large size, and are widely scattered throughout the reservoir. To date, the largest fish taken by anglers weighed

36 pounds 6 ounces and was 9 years old when captured. Generally, the population structure has changed to one of smaller, slower growing fish that are naturally reproduced. Angling success was originally localized near Glen Canyon Dam, however, more recently, fish spawned in the upper reservoir (1979-1981) have attained sexual maturity and are providing an excellent uplake sport fishery for 4-10 pound fish. The fishery in the lower reservoir is dominated by a large population of juvenile striped bass.

Striped bass creel limits were low during the 1970's when the stocking program was in place. With the discovery of natural reproduction, creel limits were increased from 2 to 4 in 1983, and 4 to 10 in 1984. The less restrictive limits were imposed to increase harvest of rapidly increasing numbers of juvenile fish. To protect the decreasing numbers of trophy fish, only 2 of the 10 fish limit may legally exceed 30 inches total length.

Physical condition of striped bass varied in direct relation to the abundance of threadfin shad, their primary food source. Growth was faster in years of abundant shad stocks and slower when shad were at a population low point.

The introduction of striped bass has been an overall success. An exciting, highly sought after fishery has developed. Angling pressure has been lessened on declining populations of largemouth bass and crappie and has been directed toward striped bass. Pelagic striped bass do not directly impact species of shorebound game fish because they generally occupy different niches. However, unlimited natural reproduction places heavy pressure on the monotypic threadfin shad forage base, and presents a monumental management challenge for the years ahead.

METHODS

Biological information was obtained from adult striped bass collected with experimental gill nets, by angling, and during creel census interviews. Data necessary to determine age and growth, food

habits, stage of maturity and condition factor (based on fork length) were routinely taken from all fish sampled. Selected stomachs were preserved in 10 percent formalin for later examination and classification of contents, including number, volume, and occurrence. Scales were taken from below the lateral line and near the posterior tip of the pectoral fin. Scale impressions were made in acetate cards with a heated press. Impressions were read and measured with the aid of a Micron XL-20 microfiche reader at a magnification of 25X.

Some fish were tagged and released at the sampling site. Floy FD-68B anchor tags were inserted with FD-67 tagging guns into the interneural rays at the base of the dorsal fin. Floy FT-4 "cinch-up" tags were inserted through the back just posterior to the soft rayed dorsal. The cinch-up tag was placed in a hollow, pointed canula which was run completely through the back leaving the tag protruding on either side. The ends were then locked together and adjusted to the appropriate length depending on fish size.

Stage of maturity of female striped bass was determined by microscopic examination of ova. Maturity stages I-III were assigned based on oil globule development (adapted from Kapke & Sheets, 1978). Stage I, immature, was a granular appearing ova that was opaque with no oil globule development. Stage II, mature, showed distinct oil globule formation beginning with 9-15 small oil droplets visible. Stage III, ripe, showed one distinct oil globule in the center of a transparent ova.

The relative abundance and distribution of young-of-the-year and juvenile striped bass was assessed with various beach seines, electrofishing gear (Job II), midwater trawl (Job I), and experimental gill nets. Biological data was routinely collected as stated above. During November, an annual survey of striped bass abundance was conducted by fishing 10 experimental gillnets for 40-42 consecutive hours (two nights and one day) at each of four previously established stations. The sample sites closely approximate those used during the spring netting survey (Job II). Nets were set in

similar shallow water rock and rubble habitat at each station. Experimental gillnets were 30.5 m long by 1.8 m deep, with four panels of 1.9, 2.5, 3.8, 5.1 cm square mesh. Catch was quantified by striped bass caught per 1000 square feet of gill net per 12 hour set following the AFS Striped Bass Committee standard method (McCloskey 1980).

Dissolved oxygen determinations were made at a suspected spawning site in Warm Creek Bay with a Yellow Springs Instrument (Model 54) dissolved oxygen meter. Dissolved oxygen concentrations and temperatures were measured at 1.5 m intervals from the surface to the bottom. Dissolved oxygen at the substrate level was measured with the probe resting on the substrate.

RESULTS AND DISCUSSION

Spawning.

Naturally reproduced striped bass were first collected in 1979 and have been collected annually since then. Two major spawning sites have been detected, one near the Colorado River inflow and one near Glen Canyon Dam. Cataract Canyon, a 19 km long river gorge at the headwaters of Lake Powell which contains 23 major rapids, has been identified as one probable spawning site. Striped bass apparently intrude less than 20 km of river above Lake Powell for spawning purposes and have not been collected above Cataract Canyon (Persons et al. 1981, Persons and Bulkley 1982). Striped bass eggs and larvae are transported in the strong spring flood currents and annually populate the upper third of Lake Powell with y-o-y striped bass. The downlake distribution of y-o-y is directly proportional to the strength of the spring flood.

Each spring since 1979, an aggregation of mature prespawning striped bass has been observed near the dam. These fish have arrived at their prespawn staging area as early as mid-February or as

late as mid-April. Striped bass which were originally stocked in Wahweap Bay near the dam and may have returned to their stocking site to spawn and/or were attracted to the strong current created as water is drawn through the penstocks for power generation. Miller (1969) found that striped bass exhibit a "homing tendency" returning to the same area each year to spawn. These prespawning striped bass remained in large schools near the dam until the females neared ovulation. The number of fish at the staging area decreased rapidly during May as they left the staging area and ventured onto the spawning grounds. A spawning site was detected within the shallow, brush covered, sandy points and coves of Antelope Island in Warm Creek Bay. Young ripe males began staging on these long sandy points in late April awaiting the arrival of ripe females.

Spawning was reportedly observed by an angler on the night of 22 May 1982 at the Warm Creek spawning site. Surface spawning activity was centered over a gradually sloping sandstone talus shoreline, mainly composed of sand with some cobble and boulder-sized substrate overlain by 2-3 mm of fine silt. Limited spawning by a few scattered groups of striped bass was also observed near the same location on the nights of 11-13 May 1984. Depth varied from 1-9 m near the observed spawning activity. Striped bass eggs were collected with ichthyoplankton nets in 1981, 1982 and 1984, and were observed by snorkeling at the spawning site in 1981 and 1982. Egg deposition was dense enough in 1981 and 1982 that dead eggs floating in the water column could be readily observed from a boat as it traversed the spawning area. Dead eggs continued to float in the upper 1 m of the water column for 5-7 days after spawning. Fertilized eggs were not collected with surface and midwater collection gear because they settled on the substrate shortly after spawning (Gustaveson et al. 1984). Oxygen/temperature profiles taken at the Warm Creek spawning site showed oxygen levels to increase from 8.4 mg/l at the surface to 13.2 mg/l on the substrate in 9 m of water (Gustaveson et al. 1984). Eggs laying on the substrate at

this particular spawning site would be exposed to more than enough oxygen to ensure normal development.

Lacustrine spawning of striped bass near the dam has stocked the lower third of Lake Powell with y-o-y annually since 1981. Lacustrine spawning probably occurs in the San Juan Arm of Lake Powell and at an increasing number of midlake areas based on collection of y-o-y during fall sampling at these locations. Spawning within the San Juan and Escalante rivers is unlikely during low water years due to the silt barriers deposited at the river mouths which prevent entry of adult fish into the tributaries. Lacustrine spawning appears to be as important, if not more important, than riverine spawning in determining the population structure of striped bass in Lake Powell.

Riverine spawning normally occurs at 15-18C, while lacustrine spawning has been detected as surface temperatures varied between 16-21C. Climatic conditions which influence spring runoff and water temperature govern spawning duration within any given year. Spawning in Lake Powell as determined by egg collection and capture of spent female fish, however, has not been seen prior to 10 May nor later than 16 June during the past 5 years. Spawning temperatures are generally reached within the lake sooner than in the rivers, which are charged with spring snowmelt.

Young-Of-The-Year Striped Bass

Y-o-y striped bass have been collected June-September with random beach seining, exploratory midwater trawling and during standardized electrofishing surveys. The y-o-y seem to prefer shallow, open, sand or clay shoreline areas. This agrees with habitat preference seen in Watts Bar Reservoir, TN (Van Den Avyle et al. 1983).

Striped bass prolarvae are capable of swimming at 4 days of age (Bonn et al. 1976) and could be expected to travel great distances

when assisted by mainstream reservoir currents. However, it has been shown that eggs and larvae spawned in the Colorado River would not explain the presence of y-o-y near the dam during most years (Gustaveson et al. 1984). Y-o-y found in the lower reservoir are more likely spawned near their collection site. Y-o-y were sampled in their highest relative abundance near the Colorado River inflow and near the spawning/staging area near the dam. Occurrence of y-o-y at midlake stations was much less frequent than seen at opposite ends of the reservoir (Table 17).

Table 17. Summary of striped bass caught during fall gillnet sampling, 1981-1984, Lake Powell, expressed in terms of fish caught per 1000 square feet of gillnet per 12 hour set.

Year & Age	Sampling Location				Yearly Average
	Good Hope Bay	Rincon	San Juan Arm	Wahweap Bay	
1981					
Age 0+	4.11	0.58	0.31	6.53	2.88
Age I+	0.58	0.26	0.05	0.63	0.38
Older STB	0.26	0.89	0.42	0.68	0.56
1982					
Age 0+	0.47	0.14	1.00	0.14	0.45
Age I+	4.91	0.52	1.52	3.24	2.55
Older STB	1.38	0.10	0.19	0.62	0.57
1983					
Age 0+	3.19	0.19	1.62	2.24	1.81
Age I+	7.10	1.48	1.76	3.43	3.44
Older STB	5.29	0.81	2.33	1.48	2.48
1984					
Age 0+	2.24	0.38	0.59	1.19	1.10
Age I+	11.07	16.76	6.29	12.39	11.63
Older STB	0.95	0.67	0.20	0.23	0.51

Recruitment

Relative abundance of young striped bass was effectively measured by fall gillnetting. The November survey seems most effective in sampling the Age I+ striped bass population. Trends in yearling abundance were the most reliable indication of recruitment and short-term striped bass population trends. Y-o-y, particularly the smaller individuals, were not uniformly sampled by gill nets and mature fish, with their selective thermal tolerance, often inhabited depths not readily sampled with a limited number of nets in a large reservoir.

The striped bass population has rapidly expanded during the past 5 years. Since 1981, the annual trend in yearling abundance has increased 30-fold, with most of the increase coming during 1984 (Table 17). The sharp 1984 increase resulted mainly from the high occurrence of yearlings at midlake stations that had previously been sparsely populated. Yearling abundance also increased at the normally heavily populated areas near the inflow and the dam but not as dramatically as seen midlake.

Physical Condition

Physical condition of healthy adult striped bass is generally highest in the springtime as gonadal tissue development increases average weight. Following spawning, K-factor immediately decreases. Condition continues to decline during the summer until the annual crop of shad attains adequate size and biomass to provide suitable forage for growth. During 1982, most adult striped bass declined physically due to very low pelagic shad populations. By November 1982, adult striped bass had an average K-factor of less than 1.0. Condition continued to decline through the winter and averaged near 0.90 during summer 1983.

Conversely, yearling striped bass and juveniles that had not attained sexual maturity (TL 600 mm) exhibited a healthy 1.3 K-factor during the same period of low shad abundance in 1982-83 (Figure 15). The K-factor anomaly can be explained by differential thermal preference between juveniles and adult striped bass. Juveniles seek water that is 20-23C but they can utilize warmer water zones. As they grow and mature, thermal preference changes to 16-20C. Adult striped bass avoid water warmer than 25C (Schaich 1979) and were repeatedly caught by anglers and charted by sonar at depths near or below the metalimnion in the summer months at Lake Powell.

Lake Powell is a warmwater impoundment typified by a high degree of thermal stratification. Stratification is greatly affected by the amount of spring overflow density current. Years with a large spring flood are characterized by a deeper, more diffused metalimnion than years when runoff is low (Merritt and Johnson 1977). The epilimnion is wedge-shaped, being thicker near the inflow than at the dam (Johnson and Merritt 1979). The cooler water of the metalimnion which adult striped bass prefer is often at depths of 15-35 m.

As Lake Powell's stratification intensifies during the summer, a distinct oxygen minimum layer develops in the upper reaches of the metalimnion. The oxygen depletion is probably the result of organic matter collecting on the denser water of the metalimnion and being oxidized at that point (Johnson and Merritt 1979).

Threadfin shad typically inhabit the epilimnion in a stratified reservoir. Following the establishment of the striped bass population in Lake Powell, the predator-impacted (Job I) shad population also sought the security of turbid water near shore and shunned the formerly safe, pelagic sanctuary they occupied when only shorebound predators existed. Consequently, a thermal separation of adult striped bass and threadfin shad has occurred annually. The vertical separation may be as much as 35 m depending on the width of the

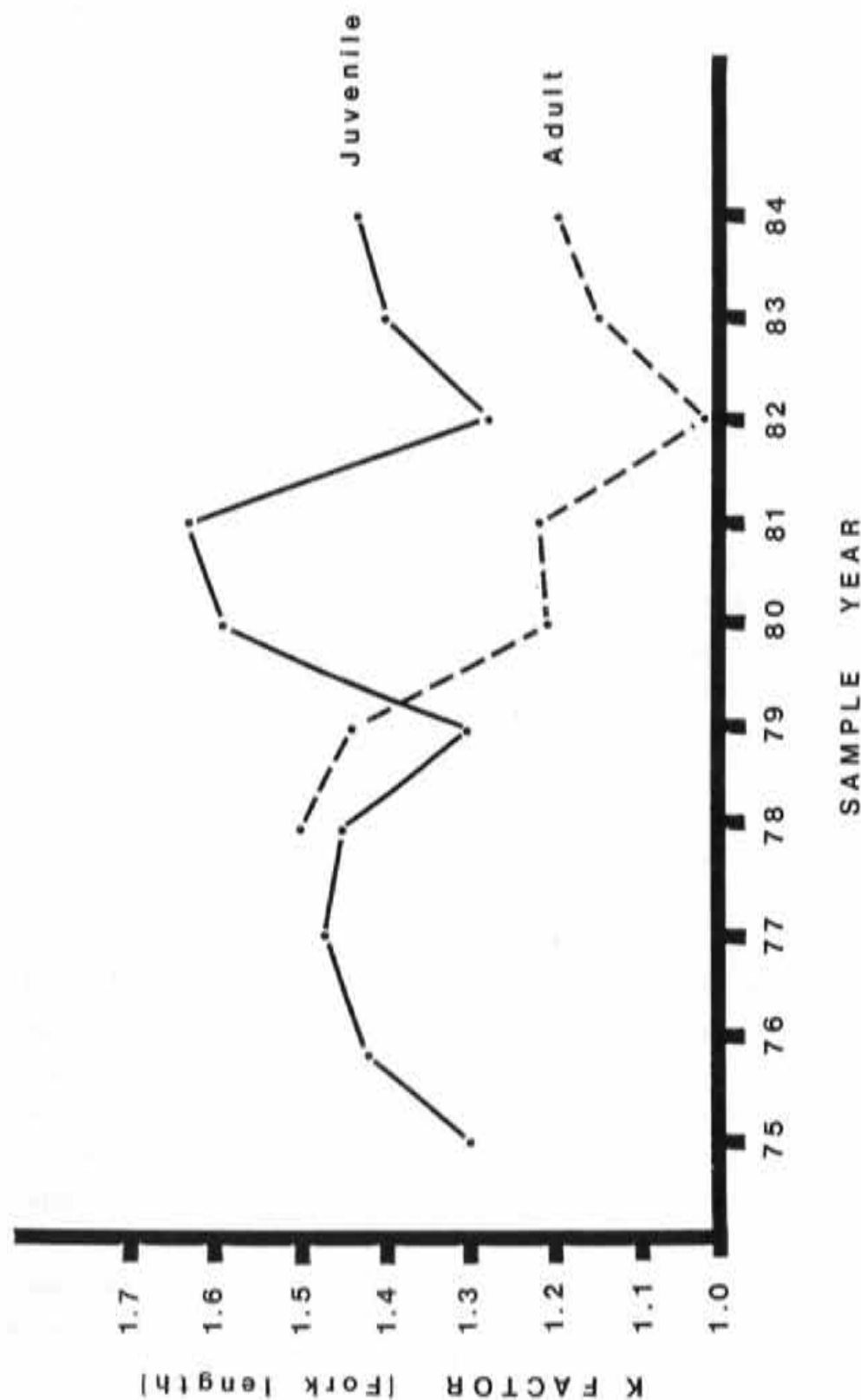


Figure 15. Yearly average condition factor (K) of adult and juvenile striped bass, Lake Powell, 1975-1984.

epilimnion and lake location. The boundary between the predator and prey was fenced by the oxygen depletion zone. An additional, horizontal, separation occurred in some cases when shad occupied the shallow, turbid water at the back of a long, gradually deepening canyon. It has been reported that a separation of "a few meters" was enough to prevent striped bass from foraging on shad in Cherokee Reservoir, TN during a severe low oxygen, high temperature situation (Schaich 1979).

Adult striped bass do eat shad in the summertime despite the thermal separation. To do so, they must leave their preferred temperature zone, cross the oxygen depletion layer, quickly forage in the warm water layer, and then retrace their path. The warm water layer was thick and shad numbers were low in 1982. Adult striped bass probably expended more energy foraging than they gained from shad consumption. The result was a general decline in body condition.

As condition declined, the ability to effectively perform the exhaustive foraging journey diminished. A decline in condition may have caused the fish to seek even cooler water where less energy is required for body maintenance (Schaich 1979), resulting in an even wider separation of predator and prey.

Juvenile striped bass were able to live in the same temperature zone (20-28C) as the shad. In 1982, the large striped bass year class produced in 1981 was never thermally separated from the small 1982 y-o-y shad population. Yearling striped bass probably reduced shad numbers in 1982 to the point that few were left for adult striped bass forage. Adult striped bass numbers were rapidly reduced by the highest angler harvest in Lake Powell history during 1982-83. Some natural mortality was suspected in fish with the poorest K-factors, although no evidence of a large-scale die-off was seen. The surviving fish scattered throughout the reservoir, perhaps in search of areas where forage concentrations were higher, such as the productive mixing zones where the tributaries enter Lake Powell.

The general reduction in numbers of adult striped bass during 1982-83, combined with recovering shad populations in 1983, allowed the adult striped bass population to show an increase in physical condition by October 1983 (K-factor 1.04). Shad production in 1984 was at a three year high and further complimented the increasing striped bass condition as K-factors returned to levels seen prior to 1982 (Figure 14). However, the striped bass population structure had changed from one dominated by older mature fish to one dominated by juvenile fish. Environmental factors, such as forage availability and thermal preference, are apparently limiting adult striped bass longevity in Lake Powell. These environmental factors favor the proliferation of juvenile fish and will probably lead to the eventual reduction in average size striped bass harvested by anglers.

Food Habits

Striped bass food habits have remained quite similar to those reported in the past (Gustaveson et al. 1980, 1982, 1983). Analysis of over 1200 stomachs has proven striped bass to be very selective feeders in Lake Powell, with threadfin shad being the single most important food item in their diet (Table 18). Crayfish (Orconectes virilis) are important during spring and summer before the annual shad crop reaches maximum abundance and contributes heavily to the diet.

In years of low shad abundance (1982-83) the number of empty stomachs increased dramatically (Table 18). Striped bass tend to feed less when shad are unavailable. Carp were usually found in stomachs of striped bass exceeding 5 kg. Due to the relative scarcity of littoral zones in Lake Powell, carp found here tend to be a pelagic schooling fish. This prey image appears to fill the needs of adult striped bass large enough to ingest a 250-300 mm carp. Occurrence of game fish was minimal throughout the study.

Table 18. Food habits of striped bass by season, expressed as percent occurrence, Lake Powell, 1980-1984.

Sample Year	December-February					March-May					June-August					September-November				
	80	81	82	83	84	80	81	82	83	84	80	81	82	83	84	80	81	82	83	84
Crayfish	11					39	13	15	43		40	29	27	37		15				
Fish																				
Shad	100	89				22	67	35		100	52	43	18		87	72	33	100		
Gr. Sunfish															7					
Lg. Bass									14											
Carp						6		20					4					4		
Red Shiner																				
Channel Cat.															14					
Unknown											4		11		6		11			
Bait																				
Anchovy																				
Waterdog						10	10	43					45	53				26		
								10												
Zooplankton						22					4		5					19		
Debris						11	10	10				14	14		14					
<hr/>																				
(n)	11	13	0	0	0	26	57	42	5	12	63	11	41	17	0	20	12	73	22	0
Percent empty stomachs	18	8	0	0	0	35	47	52	0	8	25	27	46	23	0	10	42	63	6	0

Although striped bass are not specifically preying on shorebound gamefish, it is possible they may be indirectly competing with them for shad and crayfish.

Tagging Study

Since 1981, a total of 581 striped bass have been tagged. Some 394 fish were tagged with Floy anchor tags, while 187 fish were marked with Floy "cinch-up" tags. Fish were tagged at various seasons of the year in association with other sampling. Fifty-six percent of the fish were tagged at locations downstream from Rainbow Bridge (mid-reservoir), while 44 percent were tagged at sampling locations in the upper reservoir.

A total of 18 tags have been voluntarily returned by anglers. An additional tag was returned from one fish caught in gillnet sampling in the Dirty Devil River where it enters Lake Powell. All of the tag returns by anglers came from fish that were tagged in the fall, September-November. No tags have been returned from fish tagged in the spring, summer, or winter. The 199 fish that were tagged during the fall season were generally caught with hook and line while the fish were feeding on the surface in 15-20C water. It is unclear why fish caught in shallow water with similar water temperatures during the spring have not returned. It appears that fish tagged during the heat of summer, or caught from great depths during the winter experience heavy delayed mortality and are not good candidates for our tagging study.

Tag return rate based only on 199 fish tagged in the fall totaled 9 percent. Six out of 80 anchor tags returned (7.5 percent), compared to 13 of 119 cinch-up tags (11 percent) from the fish tagged in the fall.

Striped bass movement, based on tag return data, showed adult fish tend to migrate prior to spawning. Nine of 15 returns were

from fish tagged in the lower mid-reservoir area in the fall which were subsequently harvested the following spring near the Wahweap prespawn staging areas or at the Warm Creek spawning site (Table 19). Striped bass caught after spawning season showed signs of random movement toward mid-reservoir.

Striped bass showed wide ranging, nomadic tendencies. Average distance moved between tagging and recapture was 25 miles. The range of movement varied between 0 and 50 miles.

Age and Growth

Growth of striped bass at Lake Powell has been quite consistent during the past decade. Back calculated total length at annulus formation from fish collected during 1980-1984 was approximately 20 mm less than that found in fish collected during 1975-1979 (Table 20). The slowdown in growth was not unexpected as the number of naturally reproduced striped bass increased which, in turn, increased intraspecific competition.

The greatest growth occurred during the first three years of life. Annual growth increments were 227, 202, 126, 79, 39, 33, and 80 mm for Ages I-VIII, respectively. In contrast, Atlantic Coast striped bass in Chesapeake Bay and Pacific Coast fish from the Sacramento-San Joaquin Delta averaged about 120 mm in annual growth increment for the first three years; between Ages IV and VII annual increment was approximately 60-70 mm; and after Age VIII annual increment was about 50 mm (Setzler et al. 1980). Lake Powell fish grew faster prior to maturity and then grew slower than ocean fish following maturity.

SUMMARY AND RECOMMENDATIONS

The advent of unlimited natural reproduction of Lake Powell's striped bass dictates the need to continue to monitor the impact of

Table 19. Marking, recapture, and movement history of striped bass tagged in Lake Powell, 1981-1984.

Tag No.	Date Tagged - Location	Date Returned - Location	Distance Traveled - Comment
34	3 Nov. 81 West Canyon	17 Apr. 82 Dam	35 mi downlake - spawning movement, caught at staging area
121	3 Nov. 81 Face Canyon	23 Apr. 82 Balanced Rock	21 mi uplake - spawning movement
123	3 Nov. 81 Face Canyon	28 Oct. 82 Dam	25 mi downlake - random movement
193	3 Nov. 81 Padre Canyon	8 Apr. 82 Navajo Canyon	7 mi down, 15 uplake - spawning movement
178	2 Oct. 81 Wahweap Bay	27 Aug. 82 Gansight Canyon	20 mi uplake - random movement
96	20 Sep. 81 Navajo Canyon	27 Mar. 83 Wahweap Bay	25 mi downlake - spawning movement to staging area
1880	30 Oct. 82 Last Chance	2 Mar. 83 Dam	50 mi downlake - spawning movement, at staging area
1883	30 Oct. 82 Last Chance	21 Feb. 83 Dam	50 mi downlake - spawning movement, at staging area
1894	30 Oct. 82 Warm Creek Bay	8 Apr. 83 Castle Rock	5 mi - spawning movement-caught at Warm Creek spawning site
1896	30 Oct. 82 Warm Creek Bay	2 Feb. 83 Navajo Canyon	15 mi uplake - random movement, *released*
1896	30 Oct. 82 Warm Creek Bay	25 Feb. 83 Dam	20 mi downlake - spawning movement to stage
1805	*2 Feb. 83* 31 Oct. 82 Last Chance	12 Sep. 83 Wahweap Bay	45 mi downlake - random movement
1816	31 Oct. 82 Wetherill Canyon	Apr. 83 Dam	45 mi downlake - spawning movement, caught at staging area
1877	31 Oct. 82 Wetherill Canyon	21 Apr. 83 Warm Creek	35 mi downlake - spawning movement, caught at spawning site
1815	31 Oct. 82 Wetherill Canyon	8 Mar. 83 Dam	45 mi downlake - spawning movement, caught at staging area
1289	16 Nov. 82 Red Canyon	1 Nov. 83 Red Canyon	0 - caught at same location one year later
1296	15 Nov. 82 Red Canyon	June 83 Cedar Canyon	20 mi downlake - random movement
1059	15 Nov. 82 Desha (San Juan)	3 June 83 Rincon	15 mi down San Juan, then 20 mi uplake-- random movement.
1191	27 Apr. 84 Dirty Devil River	11 May 84 Dirty Devil River	No movement - possible spawning site

Table 20. Backcalculated growth of striped bass at Lake Powell using the method of Monastyrsky.
Fish collected between 1980-1984.

Mean Estimated Lengths Backcalculated With Age Classes Separated										
Age	No. Fish	Size At Age Class								
1	79	195								
2	105	227	417							
3	94	237	438	549						
4	145	229	433	565	631					
5	157	231	434	557	641	671				
6	175	230	426	552	630	670	695			
7	90	231	424	547	631	678	706	724		
8	18	227	421	550	639	691	726	762	789	
9	1	293	510	638	727	804	891	996	1056	1095
10	3	248	459	597	688	733	794	837	892	947

Mean Estimated Lengths Age Classes Not Separated										
	1	2	3	4	5	6	7	8	9	10
1975-79a	253	440	564	663	690					
(n)	(939)	(324)	(111)	(41)	(1)					
1980-84	227	429	555	634	673	702	735	815	967	946
(n)	(865)	(786)	(680)	(587)	(442)	(285)	(112)	(22)	(4)	(3)

aGustaveson, et al. 1980.

the expanding population. The mechanism that allows lacustrine spawning to successfully occur at Lake Powell should be fully investigated. Other workers facing management decisions concerning striped bass in other waters would directly benefit from a description of the conditions required for successful lacustrine spawning.

Yearling striped bass are currently at the highest abundance level yet seen in Lake Powell. As these fish increase in age and size they will, undoubtedly, place heavy predatory pressure on existing and future shad populations. Striped bass abundance by age class, growth rates, physical condition, and food habits will continue to be important facets of this study.

Environmental conditions seem to favor the proliferation of juvenile fish and adversely affect the numbers of large striped bass (over 5 kg). Future study should help determine why relative abundance of large fish is declining and what possible corrective measures could be taken to reverse this trend.

The tagging study should be continued to increase our knowledge of in-reservoir migration and the effect this may have on striped bass distribution, seasonal sport fishery success, and shad predation by area and time of year.

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